Electrochemical and Metallurgical Industry

VOL. IV. NEW YORK, JULY, 1906. NO. 7.

Electrochemical and Metallurgical Industry

With which is Incorporated Iron and Steel Magazine

Published on the first of each month by the
ELECTROCHEMICAL PUBLISHING COMPANY,
[*Incorporated.*]
114-118 LIBERTY STREET, NEW YORK.

J. W. RICHARDS, PH. D.....*President*
E. F. ROEBER, PH. D.....*Editor*

Subscription Price: $2 per year, postpaid to any part of the world. Single copies 25 cents.

Copyrighted, 1906, by the Electrochemical Publishing Co.

Entered as Second-Class Matter, June, 1903, at the Post-Office at New York, N. Y., under the Act of Congress, March 3, 1879.

NEW YORK, JULY, 1906.

CONTENTS.

EDITORIAL 253
Announcement 253
Greeting 253
The Metal Market 254
Tar as a Liquid Fuel 254
Slags 254
Advance in Machine Shop Practice 254
The Atomic Weight in the Light of the Electronic Theory 256
German Bunsen Society—Report of Dresden Meeting. By H. Danneel. (Symposium on Fixation of Atmospheric Nitrogen.) .. 256
CORRESPONDENCE:
Why do Fluid Slags Cause Slopping in the Bessemer Converter? By Henry M. Howe 258
Metallurgical Calculations: The Heat-Balance Sheet of the Blast Furnace. By J. W. Richards 259
A New Apparatus to Determine the Melting Points of Slags. By Woolsey McA. Johnson 262
Vertical Arc Furnaces for the Laboratory. By Samuel A. Tucker .. 263
American Society for Testing Materials 264
Electric Smelting of Iron Ore. By E. Haanel 265
The Lines of Current in Storage Batteries—An Experimental Study. By M. U. Schoop 269
NOTES ON ELECTROCHEMISTRY AND METALLURGY IN GREAT BRITAIN. 271
An Electric Furnace for Heating Crucibles. By Oliver P. Watts 273
Faraday Society 275
ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS 275
SYNOPSIS OF PERIODICAL LITERATURE 277
RECENT METALLURGICAL PATENTS 281
BOOK REVIEWS:
Industrial Furnaces and Methods of Control. By E. Damour and A. L. J. Queneau 282
The Electrical Nature of Matter and Radio-Activity. By Harry C. Jones 283
Notes on Electrochemistry. By F. C. Wiechmann 283
Handbuch der Angewandten Physikalischen Chemie 283
Vol. I. Foerster on Electrolysis of Aqueous Solutions 283
Vol. II. Doelter on Physico-Chemical Mineralogy 284
Autogenous Welding of Metals by the Oxy-Acetylene Blowpipe and a New Method of Generating Oxygen. By André Beltzer 284
A New Direct-Reading Electric Thermometer 286
Thermit Repair of Gold Dredge 287
NOTES 289
PERSONAL 290
DIGEST OF UNITED STATES PATENTS. (Ozone) 290

Announcement.

With our present issue, *The Iron and Steel Magazine*, for the past eight years so ably conducted by Dr. Albert Sauveur, of Harvard University, becomes part of ELECTROCHEMICAL AND METALLURGICAL INDUSTRY. All subscribers to the former will be furnished with this journal for a period of two and one-half times their unexpired subscriptions, corresponding to the yearly subscription rates—$5.00 and $2.00, respectively. Those who were also subscribers to this journal will have their subscription extended for corresponding periods.

Greeting.

We extend editorial greetings to our new readers, former subscribers to *The Iron and Steel Magazine*. From the birth of ELECTROCHEMICAL INDUSTRY in 1902, this journal has devoted a large portion of space to the electrometallurgy of iron, steel and ferro-alloys. Since the enlargement of its title to ELECTROCHEMICAL AND METALLURGICAL INDUSTRY in 1905, we have endeavored to keep our readers abreast of current developments in the iron and steel field as reflected in the literature on the subject in all its phases. The absorption of a magazine especially devoted to this line of metallurgy, brings to us privileges and lays upon us obligations—the privilege of addressing more particularly than before the strong men of the iron and steel industry, and the obligation of living up to our responsibility to record more completely than ever before the information of most value to this class of metallurgists. While pledging our sincerity to the fulfillment of this programme we ask the coöperation of the leaders and of the rank and file of the iron and steel industry. We must get, in order to give.

* * *

This journal is devoted to chemistry and metallurgy—to their theory, engineering and practice. While absorbing *The Iron and Steel Magazine*, we intend to give no less attention than heretofore to the important broad field which we have covered in the past. The metallurgy of iron and steel—whether its theory, engineering or practice, chemical or electrical—finds its logical place within this broad field. The iron and steel metallurgist should be a chemist, an engineer and a metallurgist in general; the more he is of all these the stronger he is in his own specialty. Chemical engineering, calcination, combustion, principles of heating and reduction, fusion and casting, mechanical working and microscopical examination, measuring temperatures and quantities of heats, chimney draft, radiation, gas producers, regenerative firing and fifty other subjects—all are as widely important to the iron and steel metallurgist as to the lead, copper or zinc smelter and to the manufacturing chemist. All these subjects we aim to summarize, recapitulate and expound, and to exert in this way a broadening influence on workers and students in chemistry and metallurgy.

If technical necessity can reinforce this argument for broader interest and more liberal technique, let us cite the fact that the iron and steel industry is the chief consumer of zinc (for galvanizing), of tin (for tinning), of sulphuric acid (for pickling black iron), of nickel, tungsten, vanadium, molybdenum, manganese and chromium (for special steels), besides being a large consumer of other metals and salts. To be a broad man in the iron industry alone necessitates a considerable degree of familiarity with these correlated fields. We shall aim to do our share towards this end in the columns of this journal. In conclusion, we may recall the immense progress with which American pluck in chemical and metallurgical practice is astonishing the world in our days. To be a worthy, consistent, and—if hard work can assure it—the best exponent of this advance, is our desire and determination.

The Metal Market.

The great industrial development in the United States is forcing the consumption of metal to an unprecedented extent. The heavy buying movements in pig iron, steel, copper, spelter and lead manifest in the month of June are easily explainable. The purchasing agents desire to be covered for Autumn's requirements before they hie themselves to the seashore or mountains for their vacation, and the fact that this is done shows that in their judgment consumption is going on at a faster rate than production. Especially in copper is the market indicative of reserve strength. The price of lead is phenomenal, and at the end of May the St. Louis price of lead crossed that of spelter—a fact that three years ago would have been scouted as chimerical. All this growth, pleasing and agreeable as it is, is somewhat too extravagant and too enthusiastic to be regarded as entirely satisfactory. In times of prosperity the wise man prepares for the lean years that come on the backward swing of the pendulum of trade, and while at the present it is largely a question of maximum output, the time is coming when the maximum efficiency is requisite.

Tar as a Liquid Fuel.

Within the next few years there is pretty sure to be enormous developments of the by-product coke oven and also the gas retort to the corresponding decrease in relative importance of their respective competitors, the bee-hive oven and the water-gas producer. This progress will have the pleasant effect of reducing the smoke nuisance in our large centers. It will also increase the profit from soft coal and conserve the resources with which nature has so generously bestowed North America. A most important by-product from these two operations will be tar. Naturally, much of this tar will find increasing consumption for roofing and tarring paper. And it is to be expected besides that the fractional distillation of tar will be practiced and the aniline dye trade will be established in the United States. These and other uses will absorb a large part of the tar produced in the future. But there is a large unlimited market for tar as a substitute for fuel oil in heating furnaces used everywhere in the mechanic and metallurgical arts. The hydrocarbon burner can be made to burn tar with modifications and by preheating the tar to a point where it is fluid. In point of fact, this is being done in some plants in America successfully. We can, therefore, conclude that a great market exists for tar at from 2 to 4 cents per gallon (it must be remembered, too, that tar has higher specific gravity than oil), as a substitute for fuel in large establishments where the necessary technical ability to burn the more difficult fuel is at hand. This concatenation of facts is likely to effect most favorably the metallurgical industry both by cheapening coke and furnishing a local supply of convenient liquid fuel at a low cost.

Slags.

In this issue we publish a description of a new apparatus for the determination of the melting points of slags by Mr. Woolsey McA. Johnson. The author describes a piece of apparatus made out of Acheson graphite, to measure what he calls the "dripping point" of slags and also their rates of reduction by coke and their flow through small apertures. He follows here the same line of work as in his determination of the reduction temperature of the oxides of zinc described in our Vol. II., page 185. It is always hard to make small-scale experiments or measurements which can be applied to regular practice. But we believe that Mr. Johnson has taken special pains to meet this requirement in his apparatus, and we hope that one of the metallurgical research laboratories of our universities, perhaps aided by a grant from the Carnegie Institution, would continue these researches which relate to a subject of utmost metallurgical importance.

Advances in Machine Shop Practice.

The revolution brought about in recent years in machine shop practice can be traced to two distinct causes, the use of high-speed tool steels—intimately connected with the new industry of ferro-alloys—and the general application of the electric motor in the machine shop. In both directions the limit has not yet been reached. The present tendency to overpower machine tools indicates the possibility of further developments of high-speed steels. In all cases the development has been towards greater directness and compactness and towards the elimination of complications. In harmony with this, the general tendency is now to drive each machine tool directly by an electric motor, so that all shafting and belting is eliminated. However, there has been one singular difficulty in this development. On the one hand, to make the very best use of high-speed steels requires variable speed. On the other hand, there was not available an electric motor with suitable speed characteristics which could be built for variation of speed within the wide limits required by the best machine shop practice. This necessitated complications: either speed variation by mechanical means or a multi-wire distributing system by which a variable voltage could be delivered at the terminals of the motor and its speed thus adjusted. The first means mechanical complications, the second electrical complications. Both methods mean extra expense. How this difficulty has now been solved, is an interesting illustration of the progress of electrical engineering, and it is perhaps not superfluous to emphasize that this progress was essentially based on theoretical research. By properly studying the problems of commutation, electrical engineers have been able to develop what is needed

in machine-shop practice—a direct-current motor whose speed can be varied within wide limits. It is the new "interpole" motor to which we refer.

* * *

It is evident that the recent introduction of the auxiliary-pole motor or interpole motor—the speed of which can be changed within the widest limits—solves the problem of the machine shop in the most direct way. It is simply a motor with shunt characteristics, and its speed is varied by varying the field. Now, with the ordinary direct-current motor design large variations of the field would lead to difficulties in commutation, which would manifest themselves in sparking at the brushes and destruction of the commutator. Close analysis of the theory of commutation has, however, shown that a remedy may be found in providing auxiliary "interpoles" between the main poles. The motor is operated from an ordinary two-wire distributing system, and its speed may be varied without trouble within the widest limits required in practice. This type of motor has already become very popular in Europe. Its introduction in this country should have a far-reaching effect on machine shop practice.

The Atomic Weight in the Light of the Electronic Theory.

We have repeatedly referred in these columns to the indefatigable and magnificent work which J. J. Thomson has performed in recent years in the development of the electronic theory. Two distinct periods may be distinguished in his activity. The first period was experimental and devoted to building up our knowledge of the existence and the properties of negative electrons or, as Thomson says, corpuscles. Starting with experimental researches on cathode rays, he established the existence of corpuscles and determined their charge and mass. He further proved them to be identical when produced from different kinds of matter and under different conditions. On the basis of the facts, thus established by experiment, Thomson was then enabled to investigate theoretically by deduction what universal rôle the corpuscles play in the constitution of matter. This is the second period of his activity. His fundamental and most remarkable paper of two years ago—on which we commented at length in our April issue 1904—was devoted to the establishment of a model of the atomic structure. According to his model the atom consists of a sphere of uniform positive electrification; within this sphere a number of corpuscles or negative electrons are oscillating, arranged in a series of shells, one shell inside the other and the number of corpuscles within each shell decreasing gradually from shell to shell towards the center. Thomson showed that the stability of the structure of the atom necessitated the electrons to arrange themselves in shells, and he further showed that the properties conferred to the atom by this shell structure are analogous in many respects to those possessed in reality by the chemical elements. It is this fact which makes his model of such fundamental importance and of such timely interest.

* * *

Thomson showed especially that the properties of the atom will depend upon its atomic weight (which is proportional to the number of corpuscles in it) in a way quite analogous to the periodic law. As a matter of fact, Thomson was enabled to "explain" the periodic system, to explain the inherent reason for the groups of the periodic system (a new shell of corpuscles corresponding to a new group), to explain the variation of valence and the change from the electropositive to the electronegative character of the elements when one passes from the left to the right in a horizontal row of Mendeléef's table. As far-reaching as these results were, there still was a certain deficiency in Thomson's model, as is indicated by the above statement that the atomic weight is "proportional" to the number of corpuscles in the atom. To make the model complete we need the numerical value of the constant of proportionality between atomic weight and number of corpuscles in an atom. This problem has now been solved by Thomson in a paper published in the June issue of the *Philosophical Magazine*—which paper is again remarkable by the ingenuity of the mathematical methods employed and by the extremely simple result to which Thomson is led by his analysis.

* * *

Thomson uses three very different methods for determining the number of corpuscles in an atom of an elementary substance. The first method is based on the consideration of the dispersion of light by gases, the second on the scattering of Roentgen rays by gases, the third on the absorption of beta-rays from radioactive substances when passing through matter. All of these three methods lead to the conclusion that the number of corpuscles in an atom of an elementary substance is of the same order of magnitude as the atomic weight. Two of these methods show in addition that the ratio of the number of corpuscles in an atom to the atomic weight of the element is the same for all elements. Thomson agrees that the evidence is rather indirect, and that the data are not very numerous, so that further investigation is necessary before we can reach an exact conclusion. But the evidence at present available seems to make it highly probable that the number of corpuscles or negative electrons in an atom is directly equal to the atomic weight.

* * *

This remarkable result puts the atomic weight into a new light. By giving an electrical meaning to this fundamental chemical conception, our attention is forcibly called to the fact that the electronic theory is about to reduce all theoretical chemistry to electrochemistry. This numerical result also greatly simplifies the electronic theory of the constitution of matter. We have, indeed, the simplest possible theory which may be imagined from the electronic point of view; this is indicated by the result that a hydrogen atom contains one single corpuscle. This simplicity should facilitate further research. Finally, if the whole theory proves true, it will bear out the correctness of the views of those who, like Hinrichs, have contended that atomic weights must be whole numbers. They must be whole numbers because the atoms of two different elements differ from each other only in the number of the corpuscles constituting them. But the corpuscle itself is the same in all elements and is the fundamental thing—unless in the course of human events complications should arise which would necessitate a modification of this beautifully simple theory.

German Bunsen Society—Report of Dresden Meeting.

By H. Danneel, Ph. D.

The thirteenth annual convention of the German Bunsen Society was held in Dresden from May 20 to 24. The first session, devoted to the reading and discussion of papers, was held on Monday, May 21, and was opened by the usual graceful speeches of welcome.

Production of Nitrogen Oxides from Atmospheric Air.

A symposium of papers on this timely subject was opened by an introductory address of Prof. F. Foerster, on *the significance of the problem of the fixation of atmospheric nitrogen.*

Prof. Foerster first spoke on the chemical properties of nitrogen. Nitrogen is extremely slow in entering chemical combinations at ordinary temperatures, while oxygen combines very easily with most elements. Since oxygen may be removed from air by oxidation processes without the simultaneous formation of nitrogen oxides, it would appear that nitrogen and oxygen cannot combine with each other at ordinary temperatures. As a matter of fact, there exist a great number of stable nitrogen-oxygen compounds of which HNO_3 is technically most important.

At present we are provided by Nature with all HNO_3 used in industries and agriculture, in form of sodium nitrate and potassium nitrate. In the industries, HNO_3 is used specially for the manufacture of explosives, of aniline and other compounds of the chemistry of colors. Of greatest importance is HNO_3, for agricultural purposes, in the form of fertilizers. Nitrates of heavy metals are very unstable; they decompose by giving off NO_2. This is brown at ordinary temperature and colorless at higher temperatures, according to the formula:

$$\underset{\text{(low temperatures)}}{N_2O_4\ \text{(brown)}} \rightleftarrows \underset{\text{(high temperatures)}}{2NO_2\ \text{(colorless)}}$$

At low temperatures the equilibrium favors the brown N_2O_4, at higher temperatures the colorless NO_2. The brown gas, when introduced into water in presence of oxygen, gives nitric acid.

The direct combination of nitrogen and oxygen has first been observed by Bunsen, who found that nitric oxide is formed by explosions of mixtures of hydrogen and oxygen gases with air. To oxidize nitrogen it is therefore sufficient to employ a sufficiently high temperature, and the assumption that there is a specific electric effect in the oxidation of nitrogen by electric discharges through air cannot be maintained.[1] The nitrogen of the air was first oxidized by means of electric sparks by Cavendish and Priestley, 1780. Such a method is now used on a commercial scale. By producing discharges between iron wires with direct current at 60 to 70 volts, the brown N_2O_4 may be easily observed.

In contradistinction to other oxidation processes, the oxidation of nitrogen does not give out heat. The flame, when started, would, therefore, be extinguished, if new electrical energy was not continually supplied. The electric discharges render the nitrogen and oxygen active by producing a high temperature.

A second method for the fixation of atmospheric nitrogen is based on the property of various metals, like cerium, boron, titanium, magnesium, calcium, etc., to combine with nitrogen already at red heat, forming nitrides. In contact with water the nitrides decompose, resulting in the formation of metallic oxides (hydroxides) and ammonia. However, it is still too difficult at present to win the metals back from the oxides.[2]

A third very simple method for the fixation of atmospheric nitrogen has been invented by Adolf Frank and his collaborators. If nitrogen is blown into hot calcium carbide, calcium cyanamide $CaCN_2$ is formed.[3] This compound is also decomposed in contact with water and yields ammonia.

The following figures illustrate the commercial importance of the problem. The consumption of Chili saltpeter was one and one-third million tons in 1900, one and a half million tons in 1905, of which Germany imported about half a million tons. The world's production of ammonium sulphate in 1900 was one-half million tons, of which Germany produced 150,000 tons. About one-fourth of all nitrogen compounds is used for industrial purposes, three-fourths for fertilizers, the value of the latter amounting in 1900 to some $64,000,000.

Prof Walter Nernst then presented a paper *"on the equilibrium and the formation velocity of nitric oxide."* Prof. Nernst is at present endeavoring to secure, with the assistance of some of his students, a safe scientific foundation for the industrial fixation of atmospheric nitrogen. The present paper gives a concise review of what has so far been accomplished.[4]

There is still some dispute on the question whether the combination of N and O is a pure thermal effect or whether some specific electrical effect is involved. But the former view is undoubtedly the correct one. This is proven by the fact that the reaction $N_2 + O_2 = 2NO$ has been observed with explosions (see Bunsen's observations, mentioned above in Foerster's paper).

Such purely thermal reactions can be discussed by applying the simple principles of physical chemistry. Two problems must be answered: first, that of the equilibrium; second, that of the reaction velocity. The combination of the two gases proceeds only to a certain maximum concentration of NO, and for industrial purposes it is of importance to make this concentration as high as possible. On the other hand, the process would be useless for the industry if the reaction is very slow.

The equilibrium is determined by the law of mass action:

$$K = \frac{[NO]^2}{[O_2]\,[N_2]}$$

The chemical symbols in brackets represent the pressures of the gases after equilibrium has been reached. K is a constant independent of the relative quantities of the gases at the beginning of the reaction. K depends, however, on the temperature. By using as high a temperature as possible the concentration of NO in the gas mixture is increased.

For engineering purposes it is of fundamental importance to determine the most favorable temperature. It should be remembered that the cost of producing high temperatures increases at a higher rate than the temperature itself. For this reason it is important for industrial purposes to know how the concentration of NO in the gas mixture depends on the temperature.

This problem was investigated by Nernst by passing air into a platinum globe which was heated in an electric furnace to a certain temperature. At very high temperatures a globe of iridium was used instead of platinum. After equilibrium has been reached (*i. e.*, after the concentration of NO has reached the maximum corresponding to this temperature), it is necessary to cool the gas mixture very suddenly, so that during the cooling period it has no opportunity of assuming a new condition of equilibrium. In other words, the cooling must be done so quickly that the original equilibrium (corresponding to the high temperature) "is frozen." Already at 1,700° C. the reaction velocity of the decomposition of NO is so slow that no further decomposition may be feared.

To produce this quick cooling process, Nernst passed the gas mixture from the hot globe through a capillary tube and then analyzed it. The concentration of the constituents of the gas

[1] See also our April issue, page 122 and 136.—Ed.

[2] See, for instance, the proposal of Brode, mentioned on page 122 of our April issue.—Ed.

[3] See page 136 of our April issue.—Ed.

[4] The fundamental standpoint of Prof. Nernst in this paper is the same as that of Prof. Guye in his article in our April issue, page 136, but Prof. Nernst goes somewhat further in several details, while Prof. Guye's article covers a broader field, so that both papers supplement each other in a very gratifying way.—Ed.

mixture gives the value of K in the above equilibrium formula.

There is also another method applicable. Nernst used it to check the figures obtained by the first method. This second method consists in exploding a mixture of hydrogen and air (the latter in excess). During the explosion the temperature first increases very quickly, remains then constant for a short time, and then falls very quickly. By carrying out the explosion at different pressure, and by extrapolating the resulting curves to infinite reaction velocity, it is possible to calculate the pressure from the curves. The equilibrium constant K is thus obtained up to 2,500° C.

By integrating van't Hoff's equation,

$$\frac{d \ln K}{dT} = -\frac{q}{RT^2}$$

and by assuming the reaction heat $q = -432{,}000$, an equation for x is obtained, where x is the percentage of NO in the mixture after heating. The integration constant is found experimentally to be 0.326.

The values of x, calculated from this equation, agree extremely well with the values found by measurement. In the following table a few values of $\sqrt{K}$ and x are given, calculated from the above formula:

T	$\sqrt{K \times 10^2}$	x
1500	2.48	0.10
1800	8.51	0.34
2000	15.3	0.61
2500	45.5	1.79
3000	93.0	3.57

By further theoretical considerations Nernst finds the following values of the time t, in which one-half of the equilibrium concentration is reached at different temperatures, T:

T	1000	1500	1900	2100	2500	2900
t	81.6 years	1.3 days	2 min.	5 sec.	0.001 sec.	0.0000345 sec.

The velocity is extremely high at high temperatures and very low at low temperatures, below 1,700°. Prof. Nernst considers it to be improbable that a gas mixture may be obtained on a commercial scale containing more than 3 per cent NO, since in the removal of the gas mixture from the arc the cooling is not quick enough to prevent completely the decomposition of NO.

In the discussion the question was asked whether the concentration of NO in the mixture in the condition of equilibrium might not be essentially increased by using, instead of air, a mixture of O_2 and N_2, containing 50 per cent of each, thus corresponding to the above equation of the reaction. Prof. Nernst replied that the output would then increase by about 20 per cent, but this would hardly cover the cost for producing such a mixture of oxygen and nitrogen. Not only the equilibrium constant increases in this case but also the reaction velocity.

Prof. F. FOERSTER then presented a paper giving a summary of the industrial processes of oxidation of nitrogen which have so far been proposed. The theory clearly indicates that two main conditions must be fulfilled: to heat the gas mixture to a very high temperature, and after equilibrium has been reached to cool it as suddenly as possible.

Muthmann and Hofer, who used the electric arc, found that the output of nitric oxide is the smaller the greater the energy which produces the arc. This is explained by Brode as follows. The electric arc consists of an interior portion, which is extremely hot, and in which the nitrogen and oxygen combine. Around this interior part of the arc there is the so-called aureola, which is at a much lower temperature, but still sufficiently hot to permit the decomposition of the NO passing off from the interior part of the arc. The greater the energy supplied to the arc the greater is the aureola, and therefore the decomposition and redestruction of NO formed in the interior part of the arc.

It would, therefore, be much better to use spark discharges, since in sparks the hot zone is much more sharply defined. But since the energy of a spark is small, a great many sparks are required. This method was used in the process of Bradley and Lovejoy.[5] Their apparatus gave with a high speed of the passage of air some 2 or 3 per cent NO, yielding about 88 grams of nitric acid per kw-hour. At 10,000 volts the apparatus consumes 1 amp. per spark. If larger currents are used the sparks become surrounded with the obnoxious aureola. To use sufficiently large amounts of energy it is, therefore, necessary to employ a large number of these complicated apparatus. Prof. Foerster thinks that this has been the reason of the commercial failure of the process.

The current of a spark discharge may be increased by using it in combination with condensers,[6] but the condensers required for this purpose have not proven sufficiently durable for commercial work. If it should become possible to make cheap, durable condensers, the spark discharge will undoubtedly represent the ideal method for the oxidation of atmospheric nitrogen.

In the meantime it has been necessary to return to the use of the arc discharge, and the endeavor is to overcome the disadvantage sketched above by causing the arc either to change its place continually or to be broken continually. The process of Birkeland and Eyde[7] uses this method, and yields on a commercial scale 500 to 600 kilograms of anhydrous nitric acid per kw-year. The one and a half millions of Chili saltpeter, consumed per year in the world, could be produced by some 2,500,000 hp. Of these, Prof Foerster remarks, 500,000 hp. could be produced by utilizing in gas engines the "waste gases" of the blast furnaces in the iron district of Rhineland, Germany.

Prof. Foerster then discussed whether the combination of nitrogen and oxygen is really a purely thermal (no electrical) effect, and described experiments of his own which prove that this is the case. He finally pointed out that it will scarcely be possible to get a much higher efficiency than is now obtained in actual practice, if not a form of discharge is discovered which yields much higher temperatures. Any progress in the industrial fixation of atmospheric nitrogen must, therefore, come from advances in electrical engineering.

It might be possible to improve the efficiency by using a higher pressure of the gases, since this increases the conductivity of the air; but the equilibrium constant is not changed by the pressure.

A second improvement might be derived by using a mixture of 50 per cent of oxygen and 50 per cent of nitrogen, and liquid air might be made use of for this purpose.[8]

Prof M. LE BLANC then presented a paper on the *analytical estimation of* NO *in air*. A method for this purpose consists in passing the N_2O_4 into water and determining the quantity of nitrate and nitrite formed. The reaction is claimed to proceed according to the equation $N_2O_4 + H_2O = HNO_2 + HNO_3$; *i. e.*, equivalent quantities of nitrite and nitrate.

The author has found, however, that the ratio of nitrite to nitrate ($i:a$) is not always unity, but differs according to the conditions of the experiment. If the gas mixture is shaken with the water for a short time only, the ratio $i:a$ is indeed unity, but after shaking for 3 minutes it was found to be 1:1.7. If a KOH solution is used instead of pure water, more nitrate is obtained than nitrite. If the gases come from the reaction in a high-tension flame, the conditions were found to be reversed. In one case $i:a = 1:0.6$. The difference is greater when the gas is is sucked off directly from the arc.

---

[5] See our vol. I., pages 20, 100, 380, 386; vol. II., page 250; vol. III., page 285.—Ed.

[6] For instance, in the process of Kowalski, our vol. I., page 462; vol. II., page 152.—Ed.

[7] See our vol. II., pages 399, 507; vol. III., page 33; vol. IV., pages 23 and 126.

[8] See our April issue, page 139.

Prof. Le Blanc discussed possible theoretical explanations of these facts.

The last paper of this symposium was presented by Prof. Klandi, who discussed *the industrial change of nitrogen oxide gases into nitric acid and nitrates.* When it is stated that on a commercial scale 238 kg. NO_2 = 600 kg. of anhydrous nitric acid is produced per kw-year (Birkeland-Eyde process in Norway), it should be remembered that the gas is obtained greatly diluted, so that the cost of concentration must not be neglected. On a small scale it is possible to get per kw-year 900 kg. HNO_3, or 200 kg. of combined nitrogen in form of a gas mixture of 5 per cent concentration. We may expect that it will be possible later on to get the same results on a large commercial scale, but probably no better results.

For some water-power plants of Norway the cost of the horse-power-year is stated to be as low as $4.00; in large water-power plants of Germany and Austria this cost is about $10.00, at Niagara Falls it is $20.00. With smaller plants the cost is still higher, so that they cannot be considered for the production of NO. Low rates are possible with producer gas plants, and especially with gas plants using the waste gases of blast furnaces.

According to the above figures, the kilogram of combined nitrogen (in form of NO_2 diluted in air) is obtained on a commercial scale in Norway for 3.75 cents, while its costs 29 cents in form of Chili saltpeter and from 42 to 48 cents in form of HNO_3, according to the concentration.

For the use of NO_2 diluted in air we may first consider the direct chemical applications of NO_2, especially in the manufacture of sulphuric acid. Well conducted plants use 7 kg. $NaNO_3$ per ton of H_2SO_4, corresponding to 3.79 kg. or 1,976 liters of NO_2. This quantity is contained in 100 cubic meters of air, containing 2 per cent NO_2. But this dilution is deleterious in the manufacture of sulphuric acid, while a concentration of 5 per cent permits direct introduction into the chamber.

The following method would be suitable: absorption of the nitrogen dioxide by sulphuric acid and introduction into the Glover tower. The author calculates that a plant producing daily 250 "metric centners" of H_2SO_4 consumes 175 kg. of saltpeter, costing about $8.31. The same quantity of combined nitrogen, in form of NO_2 diluted in air, costs only $1.09. if cheap power is available as in Norway. But even if the cost of power is four times that given above for the cheapest Norwegian water-power plants (for instance, if gas engines or oil engines are used), the above cost is only $4.38 against $8.31 for the use of Chili saltpeter. This means a saving of about $1,200 per year. Even if the cost of power is eight times the cost in Norway, or $40.00 per kw-year, the use of NO_2 gases diluted in air would not be more expensive than the use of Chili saltpeter.

The most important application is, however, for the production of fertilizers, and for this purpose the NO_2 gases, diluted in air, must undergo further treatment.

Germany's agriculture now consumes 400,000 tons of saltpeter per year, the chemical industries 100,000 tons. Under the present conditions of the industrial oxidation of atmospheric nitrogen, 1,125,000 hp. would be required to fix the atmospheric nitrogen needed for Germany alone. To produce sodium nitrate from the NO_2 gases, some 25,000 carloads of caustic soda would be required per year. This would require doubling the present output in Germany.

The further treatment of the NO_2 gases is rendered very difficult by their dilution. The best method of procedure would appear to be at present to try the absorption of the gases according to the formula:

$$2NO_2 + O + H_2O = 2HNO_3$$

This has so far not been possible, not even with the aid of catalysers. However, if large quantities of water are used for absorption, the reaction is

$$2NO_2 + H_2O = HNO_2 + HNO_3$$

If through this mixture of solutions we now pass NO_2, which has been brought previously to a concentration of 50 per cent, a 60 per cent HNO_3 solution is obtained.

This reaction takes place with the development of NO, which changes again to NO_2 in contact with air. Finally, a mixture of NO and NO_2 is obtained which acts on water like N_2O_3; *i. e.* yields HNO_2 when introduced into water.

If the process is carried out successively in several absorption towers, the first tower yields HNO_3 of 60 per cent without HNO_2. In the other towers one gets HNO_3 of a smaller concentration and containing HNO_2.

Nitric acid is on the market in Germany in two concentrations: 90 per cent and 60 per cent. For four-tenths of the consumption of nitric acid in Germany 60 per cent acid is suitable, and this may contain HNO_2. The more concentrated acid which is used for explosives, should not contain more than 1 per cent of HNO_2. For transportation of the acid a change into nitrates, especially Mg $(NO_3)_2$ and Ca $(NO_3)_2$, should be considered.

In view of the large difference between the cost of the kilogram of combined nitrogen in form of NO_2 diluted in air (3.75 cents), and in form of Chili saltpeter (29 cents), the manufacture of fertilizer may be profitable even if the treatment of the gases is not very cheap. To make calcium nitrate with the aid of limestone will be the cheapest. (See page 127 of our April issue.)

Even if the cost of power should be such as to render the profit per ton of output small, yet the process may be profitable on account of the enormous consumption. Due to its hygroscopic properties, it is impossible to ship calcium nitrate in bags. Farmers are also said not to like it very much. Basic calcium nitrate is reported to prove satisfactory.

At present it is still impossible to state definitely how well this new industry will pay. The financial results also depend on the situation of the plant, freight charges, etc. Further progress may certainly be expected in the engineering problems involved.

(To be Concluded.)

Why Do Fluid Slags Cause Slopping in the Bessemer Converter?

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—No doubt many of your readers have, like myself, been puzzled as to why it is that pig iron rich in manganese causes serious slopping in the Bessemer converter, and the throwing out of large quantities of molten metal. The manganese should have the effect of making the slag thinner rather than thicker, and at first sight it seems that a thin slag should be less subject to slopping than a thick one. But after puzzling over this a great many different times I have at last seen an explanation, and I should be glad if any of your readers could throw light on its reasonableness.[1]

The explanation is simply this: that a thin slag, when a considerable quantity of it is momentarily submerged beneath the surface of the metal by the violent boiling, may, by breaking up into many small particles of drops, suddenly expose so large a surface to that metal that the evolution of carbonic oxide caused by the reaction between the iron oxide of the slag and the carbon of the metal, may be so violent as to cause slopping. In other words, the liquidity of the slag causes slopping by bringing about a very extended surface of exposure of the submerged oxidizing slag to the carbon of the metal in which it is submerged, with the consequent sudden formation of carbonic oxide, sudden generation of gas and consequent explosion.

Henry M. Howe.
Columbia University in the City of New York.
May 26, 1906.

[1] See also the abstract of the paper by Doelter, on page 289 of this issue.—Editor.

Metallurgical Calculations.

By J. W. RICHARDS, PH. D.
Professor of Metallurgy in Lehigh University.

THE HEAT BALANCE SHEET OF THE BLAST FURNACE.

Twenty-eight years ago, Sir Lothian Bell first constructed a satisfactory heat balance sheet for a blast furnace. His observations were largely, and his experience altogether, confined to the reduction of the argillaceous siderite ores of the Cleveland district, England, and although he made numerous attempts to draw general conclusions from the data at hand, applicable to iron smelting in general, yet many of his deductions remain true only for the particular ores and manner of working characteristic of the Cleveland district.

No treatment of this subject, however, can be based otherwise than upon Bell's researches, following the lines laid down in his "Principles of the Manufacture of Iron and Steel."

HEAT RECEIVED AND DEVELOPED.

The items on this side of the balance sheet are:

(1) Combustion of carbon to carbonous oxide (CO).
(2) Combustion of carbon to carbonic oxide (CO^2).
(3) Sensible heat of the hot blast.
(4) Heat of formation of the pig iron from its constituents.
(5) Heat of formation of slag from its oxide constituents.

(1) and (2) *Combustion of carbon in the furnace.* There is but one satisfactory way to determine with exactness the amounts under this heading. From the balance sheet, the total amount of carbon passing into the gases is obtained; from the analysis of the gases, the weight of carbon per unit volume of gases is calculated; the first divided by the second gives the volume of gases per unit weight of pig iron produced. The amount of CO and CO^2 in these gases is then obtained by use of the gas analysis, and if from the total CO and CO^2 in the gases there be subtracted the CO and CO^2 contributed *as such* by the solid charges, the difference is the CO and CO^2 which have been formed in the furnace. The heat evolved in the formation of these quantities can then be calculated.

Illustration: In Problem 51[1] it was calculated that per 1,000 kilos. of pig iron produced, 534.09 kg. of carbon went into the gases; also that the analysis of the gases showed 0.20736 kg. of carbon in each cubic meter of gas. The quotient indicated, therefore, 2575.6 cubic meters of gas produced per ton of pig iron. From the analysis of the gases there was in this volume,

$$2575.6 \times 0.231 = 595.0 \text{ m}^3 \text{ of CO}$$
$$2575.6 \times 0.148 = 381.2 \text{ m}^3 \text{ of } CO^2$$

whose weights were

$$595.0 \times 1.26 = 749.7 \text{ kg. CO}$$
$$381.2 \times 1.98 = 754.8 \text{ kg. } CO^2$$

The balance sheet shows, however, 49.1 kg. of CO^2 contained in the limestone flux used, which can be assumed as entering the gases bodily. Subtracting this we have 705.7 kg. of CO^2 formed in the furnace, and 749.7 kg. of CO, containing respectively

$$705.7 \times \frac{12}{44} = 192.5 \text{ kg. of C in } CO^2$$

$$749.7 \times \frac{12}{28} = 321.3 \text{ kg. of C in CO}$$

The heat generated in the furnace by the oxidation of carbon is, therefore,

$$192.5 \times 8100 = 1{,}559{,}250 \text{ Calories}$$
$$321.3 \times 2430 = 780{,}760 \text{ "}$$
$$2{,}340{,}010 \text{ "}$$

[1] See this journal, April, 1906.

If this carbon could have been entirely burnt to CO^2, there would have been generated

$$513.8 \times 8100 = 4{,}161{,}780 \text{ Calories}$$

Showing that only 56 per cent of the calorific power of the carbon was developed in the furnace; the other 46 per cent exists as potential calorific power in the waste gases, and part of it is really put back into the furnace as sensible heat in the hot blast.

There is a little doubt as to how to consider the CH^4 in the gases; that is, whether the heat of its formation should be reckoned in as developed in the furnace. This would be $(C, H^4) = 22{,}250$, or 1,854 Calories per kg. of carbon contained therein. Its presence in the gas probably results largely from the distillation of the fuel at a high temperature, and the heat required to disunite the CH^4 from the solid fuel is probably as great as is represented by its heat of formation from carbon and hydrogen. The item is, therefore, a doubtful one, and as far as we know, we may be coming about as near to the truth by omitting it altogether as by counting it in. If we wished to add it in the illustration just given the calculation would be:

$$\text{Volume of } CH^4 = 2575.6 \times 0.005 = 12.88 \text{ m}^3$$
$$\text{Weight of C} = 12.88 \times 0.54 = 6.9 \text{ kg.}$$
$$\text{Heat of formation} = 6.9 \times 1{,}854 = 12{,}793 \text{ Cal.}$$

It should be emphasized that in this calculated heat of oxidation of carbon in the furnace, no account has been taken whatever of *where* in the furnace this heat is generated. Above all, the mistake should not be made of supposing that the 780,760 Calories produced by formation of CO represents the heat generation at the region of the tuyeres; nothing could be further from the truth. A great deal of carbon is burnt to CO at the tuyeres, and some above the tuyeres, but a goodly proportion of this CO oxidizes by abstracting oxygen from the charge and becomes CO^2. It would not be incorrect, however, to divide the heat of oxidation of carbon in the furnace into two parts, viz.: to assume all the carbon as first forming CO, and part of this CO afterwards forming CO^2, corresponding to the amount of the latter formed in the furnace. If this were done, we would have

$$513.8 \text{ kg. C to CO} = 513.8 \times 2430 = 1{,}248{,}535 \text{ Cal.}$$
$$449.2 \text{ kg. CO to } CO^2 = 449.2 \times 2430 = 1{,}091{,}475 \text{ "}$$
$$2{,}340{,}010 \text{ "}$$

This analysis gives us the information that of the total heat generated by the oxidation of carbon in the furnace, somewhere about one-half is generated by its burning to CO, and the other half by the further oxidation of CO to CO^2; and we also know that the larger part of the former takes place at the tuyeres, and all of the latter takes place during the reduction of the charges in the upper part of the furnace.

If we know, however, or have calculated the amount of the blast received by the furnace, or, more properly speaking, the amount of oxygen in the blast, then the heat generated by oxidation of carbon at the tuyeres becomes known. In the previous illustration, taken from Problem 51, we can also take from the same problem the weight of oxygen in the blast, 557.7 kilos. This would burn $557.7 \times 0.75 = 418.3$ kg. of carbon to CO at the tuyeres, generating there

$$418.3 \times 2430 = 1{,}016{,}410 \text{ Calories,}$$

or 44 per cent of all the heat generated by oxidation of carbon in the furnace, leaving 1,323,610 Calories as generated above the tuyeres by the agency of the oxygen of the charges. These figures tell us just where and how the principal items of heat were generated in this particular furnace, and the similar calculation may be made for any blast furnace for which we have the necessary data.

(3) *Sensible heat in the hot blast.* To calculate this item, we need to know the weight or volume of the different constituents of the blast and their temperature. The question at once arises, as to what base line of temperature shall be chosen. It is most convenient to choose 0° C., since that is

not over 15° from the average temperature in the largest iron producing countries. However, any other prevailing temperature may be taken as the base line, involving merely a little more calculation, since our specific heats are reckoned from 0° C. The temperature ought, moreover, to be taken as near to the tuyeres as possible, to properly take into account the effect of cooling of the blast in the bustle and feeder pipes, from radiation and expansion. The blast consists of air proper and moisture, the former with a mean specific heat between 0° and t° C of $0.303 + 0.000027t$, in kilogram calories per cubic meter, or in ounce calories per cubic foot, the latter with a similar mean specific heat of $0.34 + 0.00015t$. Since the moisture at times amounts to as much as 5 per cent of the blast, it should be calculated separately.

Illustration: With the outside air at 30° C., and saturated with moisture (raining), calculate the heat carried into a blast furnace by blast carrying in 1859.1 kilos. of nitrogen, the temperature of the heated blast being 600° C. Barometer 720 millimeters of mercury. Temperature base line 0° C.

Solution: One cubic meter of the moist blast, as taken into the blowing cylinders, carries all the moisture it can hold, the tension of which is therefore 31.5 millimeters. The tension of the air proper present is therefore $720 - 31.5 = 688.5$ millimeters, and each cubic meter of moist air carries

$$\frac{31.5}{720} = 0.0438 \text{ cubic meter of moisture, and}$$

$$\frac{688.5}{720} = 0.9562 \text{ cubic meter of air proper.}$$

Whatever the temperature of the blast, the moisture and air proper will be in this same proportion whenever its temperature is over 30° C. If the temperature were 0° C. the moisture would be mostly condensed, but for the purposes of calculating the heat brought in we may assume the moist air to be at 0° C., with its moisture uncondensed. That volume of blast which would be 1 cubic meter at 0° and 760 mm. pressure, would, therefore, bring in, at 600° C., the following quantity of heat:

H^2O	$0.0438 \times [0.34 + 0.00015\ (600)] \times 600 =$	11.3 Calories
Air	$0.9562 \times [0.303 + 0.000027\ (600)] \times 600 =$	179.7 "
	Total	191.0 "

Since the nitrogen present in this is

$$0.9562 \times 1.293 \times \frac{10}{13} = 0.9511 \text{ kg.}$$

the heat brought in per 1859.1 kg. of nitrogen is

$$191.0 \times \frac{1859.1}{0.9511} = 373{,}344 \text{ Calories.}$$

An amount equal to over one-third of all the heat generated by combustion of carbon at the tuyeres.

(4) *Heat of formation of pig iron from its constituents.* The pig iron contains several per cent, some 5 to 10 altogether, of carbon, silicon, manganese, phosphorus, sulphur and other elements. The energy of their combination with the iron is a somewhat indefinite quantity, and in no case can be considerable. Berthelot states the energy of combination of carbon with iron as $(Fe^3, C) = 8{,}460$, which would be 705 Calories per kilogram of carbon, and another investigator (Ponthière) states the heat of combination of phosphorus with iron to be zero. In the present state of uncertainty it is hardly allowable to add in any other than the heat of combination of the carbon in the iron, and leave out that of the other elements.

(5) *Heat of formation of the slag from its constituent oxides.* Here we touch upon a quantity of more than insignificant proportions, yet which is not yet quantitatively known with satisfactory accuracy. The main constituents of the slag are SiO^2, Al^2O^3, CaO, MgO and CaS, which are provided by clay, limestone and iron sulphide. If we allow, on the other side of the balance sheet, for the heat necessary to de-hydrate clay, drive carbonic acid off carbonates, and break up iron sulphide and enough CaO to furnish Ca for CaS, we are then entitled, on the other hand, to place in the heat evolution column the heat of combination of aluminium silicate with lime and magnesia, the heat of formation of CaS and its heat of solution in the silicate slag. The heat of formation of CaS is 94,300 Calories, or 2,947 Calories per kilogram of sulphur; its heat of combination with a silicate slag is unknown. The heat of combination of lime with aluminium silicate has been determined only for the proportions 3CaO to $Al^2Si^2O^7$, that is, for 168 parts of CaO uniting with 222 parts of aluminium silicate. This has been determined in Le Chatelier's laboratory as $(3CaO, Al^2Si^2O^7) = 33{,}500$ Calories, which is 200 Calories per unit of CaO combining, or 150 calories per unit weight of $Al^2O^3 + SiO^2$. The calculation would be made on the basis of the amount of lime (plus lime equivalent of magnesia present), if it were present in a smaller ratio than 168 to 222 of silica and alumina, and on the basis of the silica and alumina, if their ratio to the summated lime were less than 222 to 168. It is probable that in the near future these quantities will be known more accurately.

One item of heat received by the furnace has not been mentioned, because of its usual absence, viz.: heat in hot charges. Very rarely roasted ore comes hot to the furnace, in which case its sensible heat must be counted in, else the thermal sheet of the furnace will be that much out of balance.

Heat Absorption and Disbursement.

The items on this side of the balance sheet are:

(1) Sensible heat in wase gases, including water vapor only as vapor.
(2) Sensible heat in outflowing slag.
(3) Sensible heat in outflowing pig iron.
(4) Heat conducted to the ground.
(5) Heat conducted and radiated to the air.
(6) Heat abstracted by cooling water, tuyeres, etc.
(7) Heat for de-hydrating the charges.
(8) Heat for vaporizing water from charges.
(9) Heat absorbed by decomposition of carbonates.
(10) Heat absorbed in reduction of iron oxides.
(11) Heat absorbed in reduction of other metallic oxides.
(12) Heat absorbed by decomposition of moisture of the blast.

(1) *Sensible heat in waste gases.* The amount of these gases is known only from the carbon contained in unit volume, by analysis, and the known weight of carbon entering and leaving the furnace. If there is much fine coke carried over by the blast, allowance must be made for the carbon in it, because this would not be represented in the gas analysis. The analysis of completely dried gas is that usually obtained, because if the gas is measured without drying, an uncertain amount of moisture is condensed, and, therefore, it is usual to dry before measuring and analyzing. The amount of moisture in the gases is either assumed as that driven off from the charges, as shown by the balance sheet, or else is determined directly by drawing the gases through a calcium chloride tube or other dessicating apparatus. Several tests should be made to get a fair average, because much more will be in the gases immediately after charging than immediately before. Dust must be excluded from the drying tube by filtering the gases through dry asbestos. The average temperature of the gases should be known over a considerable period; a thermo-couple in the down-comer gives this most accurately and more uniformly tnan if inserted above the stock line in the furnace.

The weight of moisture per unit volume of dry gas is then converted into volume at standard conditions by dividing by 0.81 (1 cubic meter = 0.81 kg; 1 cubic foot = 0.81 ounce avoirdupois). The sensible heat of the gases is then calculated, using 0° C. as the base line, and the proper mean specific heats

of the gases per unit of volume. The water vapor will here be considered simply as a gas, and its sensible heat above water vapor at 0° only calculated. This leaves the latent heat of vaporization of this water to be considered as a separate item (606.5 calories), that is, as heat absorbed by reactions in the furnace, thus putting it on exactly the same footing as the CO^2 in the gases which has been expelled from carbonates in the furnace. By so proceeding much uncertainty as to the heat in the water vapor is avoided.

If the amount of flue dust is considerable its quantity should be ascertained, and the heat in it also calculated and added in to the heat in the moist gases. Its specific heat may be approximated as so much carbon, iron oxide and silica, the proportions of each of these present being known.

(2) *Sensible heat in outflowing slag.* The weight of slag produced is seldom taken directly, but can be reckoned up with all needful accuracy from the balance sheet of materials entering and leaving. Its temperature and specific heat, solid and liquid, melting point and latent heat of fusion, are unfortunately almost always unknown factors. The one datum which is needful, however, is the total heat in a unit weight of liquid slag as it flows from the furnace, and this is not a difficult quantity to obtain. A rough calorimeter with a reliable thermometer and containing a carefully weighed quantity of water, may be easily constructed. Some liquid slag is run directly into it, and by observing the rise of temperature and afterwards filtering out, drying and weighing the granulated slag, a satisfactory determination can be arrived at. This is corrected to 0° C. by using an approximate specific heat, say 0.20, for the range of final calorimeter temperature to zero. In this connection it is important to note that the calorimetric determinations of Akerman on blast-furnace slags, give the heat in the *just-melted* slag, whereas slags flowing out of a furnace are considerably, some 200° to 500° C., above their melting point, and therefore contain some 50 to 150 Calories more heat than that given by Akerman for a slag of similar composition. Since Akerman's values run from 350 to 400 Calories, the actual heat in the outflowing slag may be between 400 and 550 Calories. Akerman himself states that an average of twenty-seven Swedish furnaces gave 530 Calories as the actual heat in unit weight of outflowing slag, and Bell uses 550 in most of his calculations on Cleveland (England) furnaces.

(3) *Heat in outflowing pig iron.* The heat in *just-melted* pig iron is evidently too small a quantity to use in this connection. The heat in the outflowing pig iron at 200° to 500° above its melting point will be 50 to 100 Calories greater. The former quantity is about 245 calories; the latter will be 300 to 350. Bell takes 330 for Cleveland furnaces; Akerman states 250 to 325 for Swedish furnaces. We may conclude, then, to use 300 Calories for a coke furnace running cool, and up to 350 Calories for a very hot furnace.

(4) *Heat conducted to the ground.* This is a very uncertain quantity. It varies with the kind of ground, and is more nearly a constant per day than per unit of pig iron produced. It is, therefore, expressed per unit of iron produced, larger for small furnaces run slowly than for large furnaces run fast. It is less when running rich ores and greater with poor ores, other things being equal. As nearly as can be assumed we would put this item as lying between 60 and 200 Calories per unit of pig iron made. Bell uses 169 on one Cleveland furnace, but it is certainly less than 100 in some charcoal furnaces using pure ores and fuel, and consequently with a small heat requirement.

(5) *Heat conducted and radiated to the air.* This item is likewise more nearly a constant quantity per day for a given furnace, and is therefore less per unit of iron produced the faster the furnace is run. It may vary between 60 and 250 Calories per unit of pig iron, the former in furnaces of low heat requirement per unit of iron produced, the latter in those of high heat requirement. If the amount were calculated it would figure out as a time function, and would require the temperature of the outside shell, that of the air, the velocity of the wind, and the total outside surface, in order to calculate by the principles of heat radiation and conduction, the amount radiated per day. No one has done this yet for any one furnace, and, in brief, items (4) and (5) of this schedule are usually grouped together and determined simply by difference, their sum aggregating from 100 to 500 Calories per unit of pig iron, averaging 100 to 150 for charcoal furnaces of low heat requirement, 200 to 450 for Cleveland furnaces (Bell), and 300 to 500 for large, modern furnaces with thin walls and great height.

(6) *Heat abstracted by cooling water.* In the old-fashioned heavy masonry, cold blast furnace, this item was zero. With the advent of hot blast, the water needed for cooling the tuyeres entered as a heat abstracting factor. It is greater the harder a furnace is blown, but does not increase proportionately with the output. The heat lost by tuyere-cooling water may be 50 to 100 Calories per unit of pig iron made. That for cooling of bosh plates and the outside of the crucible in modern furnaces, may vary all the way up to 200 Calories. These two items are very large in a modern furnace, but are necessary expenditures of heat energy in order to preserve the lines of the furnace during fast running. For any particular furnace they may be determined with all needful accuracy by measuring the amount of water pumped or used for these purposes and its temperature before and after using.

(7) and (8) *Drying and de-hydrating charges.* Water goes into the furnace as moisture and as combined water of the charges. To convert the moisture, such as is evaporated by a current of moderately warm air, into vapor requires 606.5 Calories per unit of water. This allows merely for its vaporization in the furnace, and not for any sensible heat which it may carry out of the furnace at the temperature of the waste gases. This latter item is properly considered in with the sensible heat of the waste gases. The common practice of saying that it takes 637 Calories to evaporate the moisture of the charges is wrong, because this amount would convert water at 0° to vapor at 100°, and, therefore, would include part of what is properly the sensible heat of the waste gases. On the other hand, it is equally wrong to say that this heat of vaporization should be counted in as sensible heat in the hot gases; it would be just as logical or, rather, equally illogical, to count the latent heat of vaporization of CO^2 as sensible heat in the gases.

To drive off water of hydration from hydrated minerals in the charge requires an additional amount of chemically-absorbed heat. As far as is known, this is small for the water driven off hydrated iron oxides, so small as to be a doubtful quantity and safely left out; but if it comes from clay the large amount of 611 calories is absorbed in merely separating it from its chemical combination ($2H^2O$, $Al^2Si^2O^7$) = 22,000 Calories, which would require 611 + 607 = 1,218 Calories to put into the state of vapor each unit weight of water entering the furnace chemically combined in clay. (This does not concern the ordinary moisture in moist clay, expelled at 100° C., but only the combined water in the dry clay). Where much clay occurs in the ores this quantity becomes important, and its amount explains some of the difficulties met in working clayey charges, particularly since a large part of this chemically combined water is expelled only at a red heat, and, therefore, cools greatly the hotter zones of the furnace.

(9) *Decomposition of carbonates.* Raw limestone, or dolomite, is the usual flux of the blast furnace, and its carbonic acid is evolved at temperatures between 600° and 800°. Whether some of this is subsequently decomposed by contact with carbon and reduced to CO, is immaterial to the balance sheet, because more than enough CO^2 escapes from the furnace to represent the CO^2 of the flux, and we charge the furnace only with the formation of the CO and CO^2 actually found in the gases, less the CO^2 from fluxes. Bell charges up

the heat absorbed also in the assumed reaction $CO^2 + C = 2CO$, but this is an error, because it is doubtful how much of the CO^2 is thus decomposed. and the question, in its last analysis, is one of heat *distribution* in the furnace, and does not concern the totals of heat absorbed or evolved. We can, therefore, omit the item of decomposition of this CO^2 (as likewise, and for analogous reasons, the heat evolved in carbon deposition in the upper part of the furnace — $2CO = C + CO^2$), and need consider only the heat required to expel the CO^2 from carbonates. This is:

(CaO, CO^2)	= 45,150 Calories	= 1,026 Calories	per kg. CO^2
(MgO, CO^2)	= 29,300 "	= 666 "	"
(MnO, CO^2)	= 22,200 "	= 500 "	"
(FeO, CO^2)	= 24,900 "	= 566 "	"
(ZnO, CO^2)	= 15,500 "	= 352 "	"

By using the above figures. in connection with the known composition of ore and fluxes, the heat required to decompose carbonates can be correctly calculated.

(10) *Reduction of iron oxides.* The heats of formation of the various oxides of iron are:

(Fe, O)	= 65,700 Calories	= 1,173 Calories	per kg. iron
(Fe^3, O^4)	= 270,800 "	= 1,671 "	"
(Fe^2, O^3)	= 195,600 "	= 1,746 "	"

And, therefore, just these quantities of heat are required per unit weight of iron reduced from these compounds. If the ore is a carbonate the heat absorbed in driving of CO^2 from $FeCO^3$ can be first allowed for, and then the heat required for reduction of the FeO calculated on the weight of the reduced iron. If some FeO goes into the slag it will be as FeO, and if the ore was Fe^2O^3, or Fe^3O^4, the reduction of unit weight of iron from the state of Fe^2O^3, or Fe^3O^4, to the state of FeO, absorbs respectively 573 or 498 Calories, as may be readily deduced from the heats of formation of the three oxides concerned. If FeS is present its heat of formation is

(Fe, S) = 24.000 Calories = 429 Calories per kg. Fe.

If the iron is charged partly as silicate, such as mill or tap cinder, an additional amount of heat will be required for reduction, equal to that needed to separate the iron oxides from their combination with silica. The heat of formation of the bi-silicate slag only has been determined:

(FeO, SiO^2) = 8,900 Calories = 148 Calories per kg. SiO^2.

And since the cinders concerned contain relatively more iron than this, we can best make allowance for the heat required to set free the silica. It is necessary, therefore, to take the amount of silica in the iron cinder charged, and allow, as necessary for its decomposition into FeO and SiO^2, 148 Calories for each unit weight of SiO^2 contained.

(11) *Reduction of non-ferrous oxides.* Silicon is usually present in pig iron, its reduction from silica requiring:

(Si, O^2) = 180,000 Calories = 6,413 Calories per kg. Si.

There is a little doubt about this (Berthelot's) figure; more recent determinations, not yet published, point rather to 196,000 and 7,000 Calories respectively.

Manganese is often present in the ores as MnO^2, Mn^2O^4, or MnO^2, and going partly into the slag as MnO. The heat absorbed in reduction to manganese is:

(Mn, O)	= 90,900 Calories	= 1,653 Calories	per kg. Mn
(Mn^2, O^4)	= 328,000 "	= 1,988 "	"
(Mn, O^2)	= 125,300 "	= 2,278 "	"

For the MnO produced and going into the slag, the reduction from Mn^2O^3, or MnO^2, per unit weight of contained manganese, absorbs 335 or 625 Calories respectively.

Sulphur generally comes from the reduction of FeS, requiring 667 Calories per kg. of sulphur; but care must be taken not to allow for this heat twice, since if reckoned once under the head of iron reduction it must not be reckoned on the balance sheet a second time under sulphur. One reduction of FeS liberates both constituents.

Phosphorus may be reduced in large quantity in making basic iron. It probably comes mostly from calcium phosphate, in which case we must reckon on not only the heat of oxidation of phosphoric oxide but also its heat of combination with lime:

(P^2, O^5)	= 365,300 Cal.	= 5,892 Cal. per kg. of P.
$(3CaO, P^2O^5)$	= 159,400 "	= 2,410 " " contained.

Making a total heat requirement of 8,302 Calories to separate unit weight of phosphorus from phosphate of lime, and leave free lime. In a furnace making a pig iron with several per cent of phosphorus, this item becomes quite large.

Calcium occurs in the slag as CaS, its reduction from lime requiring

(Ca, O) = 130,500 Calories = 3,263 Calories per kg. Ca.

Other elements than the above rarely occur in pig iron in notable quantity. If rare ones occur, their heat of reduction can be sought in thermochemical tables. Those of tungsten, titanium, molybdenum and chromium are, however, not at present known.

(12) *Decomposition of moisture in the blast.* This is to be counted as vapor of water, the heat required to decompose, which is:

(H^2, O) vapor	= 58,060 Cal.	= 3,226 Cal. per kg. H^2O.
		= 29,030 " " H^2.

It is not correct to allow here for the sensible heat in this water vapor coming in with the hot blast, because that heat should go on the other side of the balance sheet as heat delivered to the furnace. Neither is it correct to subtract the heat of combination of the oxygen of this moisture with carbon to form CO at the tuyeres; because, although that combination actually does take place, yet the heat thereby evolved properly belongs also on the other side of the balance sheet, and is there properly taken care of as part of the heat of oxidation of carbon in the furnace.

A New Apparatus to Determine the Melting Points of Slags.

By Woolsey McA. Johnson.

A slag is essentially a complex silicate of several bases. Most prominent among these latter is calcium oxide, and in lead or copper blast-furnace work ferrous oxide. The several silicates usually crystallize out in the process of cooling, so that slag has not a sharp melting point in most instances.

An accurate knowledge of the "running temperature" of the slag is, of course, of great importance in any work in which it is necessary to produce a liquid slag under given metallurgical conditions, as in lead furnace practice, or to prevent the formation of slags, as in the zinc retort. The literature of the subject does not offer such data as were satisfactory, for in all cases the point determined is the uncertain "softening point." Such results are not directly translatable into actual practice, unless subject to great corrections from the basis of practical knowledge.

While working some years ago on a small "nickel brick cupola" of the Orford Copper Co., I had the opportunity, at the end of the short weekly campaign, just as the cupola furnace was going out of blast, of observing the process of slag formation on the coke through several of the small holes which were then appearing in the sides of the furnace. With the knowledge of this phenomenon in mind, I devised the following piece of apparatus to give results as directly applicable to practical work as was possible. The first execution of the work was done at the instance of Mr. Fred. W. Gordon, chief consulting engineer of the Lungwitz Reduction Co., at Warren, N. H., in the summer of 1905. A discussion of the characteristics of proper slag for this interesting metallurgical operation discloses certain conditions entirely and distinctly novel. And for this purpose my design proved quite serviceable and neat.

A round 4-inch bar of Acheson graphite was sawed off by a

carpenter's saw in 3½-inch lengths, a narrow slot, ⅝ inch wide and 1½ inches high, was then cut in bottom of this. In top a hole 1 inch in diameter was drilled with machine drill to a depth of 1 inch. This was continued to by a 7/32-inch hole to the narrow slot.

A horizontal 1-inch hole was drilled above line of lower slot to receive a Le Chatelier pyrometer to a point as near as possible to the 7/32-inch "dripping hole." Small proportions of

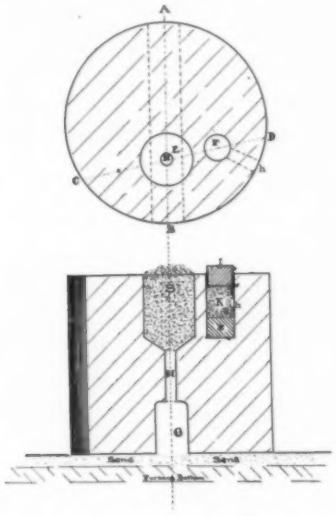


FIG. 1.—TESTING SLAGS.

the formed-slag, or slag-making materials, were placed in upper hole. The entire apparatus was placed in a special oil-fired experimental reverberatory furnace with a sand layer over hearth. The pyrometer was inserted through the hole in one side of the furnace.

The observing hole was on the opposite side of the furnace, and a view could be had of the slag directly through the slot when the slag reached the "dripping point," and dropped or ran through, depending on its viscosity.

The fact that the pyrometer couple was so close to the slag

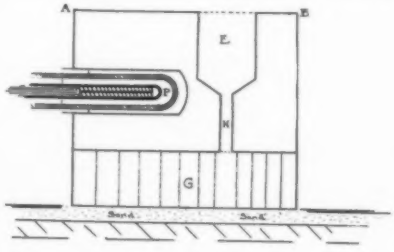


FIG. 2.—TESTING SLAGS.

at this critical temperature increased the accuracy of results. Even though slag is a poor conductor of heat, Acheson graphite is so good a one that the temperature gradient is small.

To ensure a check on the pyrometer we bored a ½-inch hole in one side, put 5 grams of zinc in this hole, covered with charcoal, and each time checked 1 pyrometer to the boiling point of zinc, about 918° C. at the altitude of Warren. The characteristic snaky flame of zinc vapor came through small 7/32-inch horizontal on side. The ½-inch hole was plugged with a whittled graphite plug.

The apparatus was also made much larger, and by allowing slag to drip through granulated coke column, 3 inches in diameter 4 inches high, we measured the rate of reduction of reducible oxides, FeO and ZnO. I also designed another apparatus something in appearance like an hour-glass, by which I propose to measure rate of flow of slags through a small apperture at different temperatures.

Apparatus of other material than Acheson graphite is not to be considered. Fire-clay would flux with slag directly and iron would oxidize, and iron oxide so formed would flux with any slag.

Results on some 150 typical slags were very gratifying, and determinations checked often to 5° C., although insufficient in number, because of necessary rapidity of work. The work discloses not only corroboration of practical knowledge but also new and unlooked-for quantitative data on this vast subject.

As it will be impossible for me to continue this work on the scale necessary, I will gladly give any advice on the subject to anyone with proper laboratory facilities. It certainly deals microcosmically with the operations of the blast furnace.

Vertical Arc Furnaces for the Laboratory.

BY SAMUEL A. TUCKER.

Graphite as manufactured by the Acheson process is a material which lends itself admirably to the construction of electric furnaces, and this is due to three causes: the ease with which it may be machined or shaped to the purpose required, its high electrical conductivity, and its freedom from impurities. It is, therefore, a most suitable material for the construction of electric furnace parts which are required to withstand a high temperature and in which the addition of carbon is of slight importance.

The vertical arc or pot furnaces, as used for some time past in this laboratory, are constructed after the pattern of the

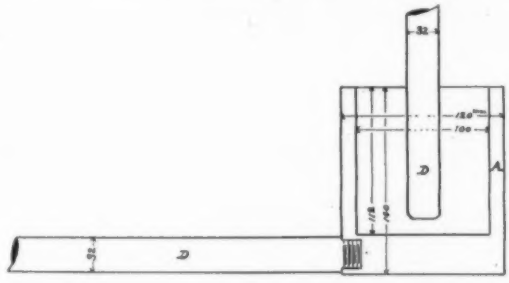


FIG. 1.—VERTICAL ARC FURNACE. ELEVATION.

Willson furnace, as shown in Fig. 1. *A* is the crucible, with the dimensions as given, *D* and *D'* are the electrodes, the material being of Acheson graphite. The horizontal electrode *D* is united to the crucible at *J*, the crucible being bored out and tapped for this purpose to admit the threaded end of *D*. The vertical electrode *D* is held by means of an appropriate clamp and means by which it may be raised and lowered at will.

The crucible *A* is turned from a solid electrode 5 inches in diameter, and this operation can be accomplished in the lathe in about 20 minutes, a cut of 3-16 inch being taken at a speed of 230 feet per minute with a feed of about 4 inches per minute. These figures are, of course, dependent to a certain extent on the operator, but the job need not take over 20 to 25 minutes, including the chucking of the work.

The crucible is surrounded with a heat-insulating material and brick retaining walls, as in Fig. 2, in order to protect the graphite from oxidation and prevent loss of heat by radiation from the walls. The choice of material for this packing is a question of heat conserving and refractory qualities, and it has been found that slaked lime of powdery condition, as obtained from the barrel after it has stood about the laboratory for a time, gives satisfactory results.

The electrodes, which are the regular 1¼-inch diameter, will take 300 amps. for some time without undue heating, and for short runs the current can be raised considerably above this figure.

In using this furnace the arc is struck on the bottom of the crucible, and the charge fed in and subjected to the heat action of the arc from the charge to electrode *D*.

If the desired product is in the molten condition, alloys, etc., the vertical electrode is raised out of the way, the electrode holder, as in *I*, Fig. 2, disconnected, and the crucible lifted with a pair of tongs together with the horizontal electrode *D'*,

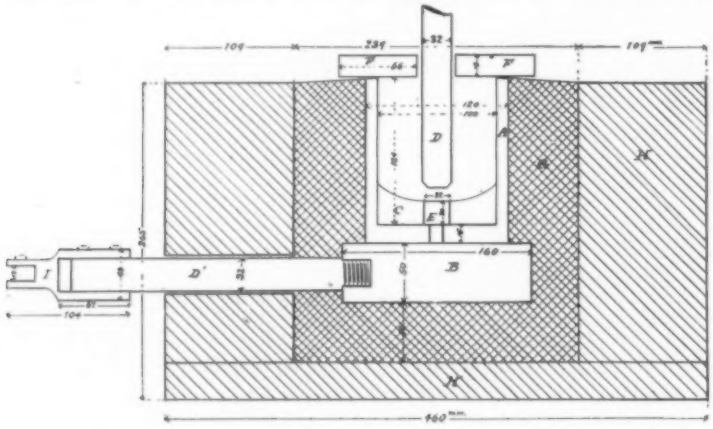


FIG. 2.—VERTICAL ARC FURNACE. ELEVATION.

and the contents poured out into a mould. In case the product cannot be poured, carbides, etc., it is taken out by the chisel from the crucible after it has cooled, and it is remarkable what an amount of hard treatment a crucible of this kind will stand.

The chief objection to this type of furnace is that the charge is brought in direct contact with the arc, and the temperature at this point is consequently raised far above that which is necessary to bring about the desired reaction. The consequence is that volatilization takes place at this point to such an extent that the yield is reduced very materially. To obviate this the duration of the run has to be shortened, and the bulk of the charge is not raised to a high enough temperature, particularly if it is placed at some distance from the sphere of the arc. So we then have a case of too high a temperature at one place and not enough at the other.

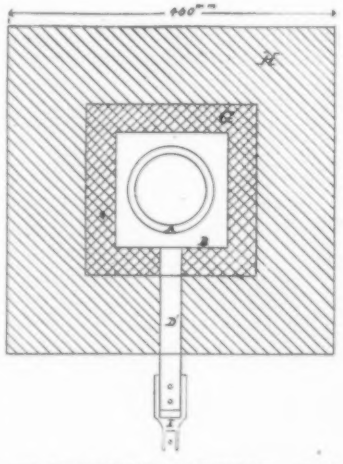


FIG. 3.—VERTICAL ARC FURNACE. PLAN.

A furnace of the Moissan type overcomes these difficulties to a great extent, as the temperature is maintained by the radiant heat from the arc, but furnaces of this type are somewhat difficult to construct, lack durability, and the charge is unevenly heated, that at the top of the containing crucible or opening being subjected to the highest temperature, while that at the bottom being comparatively far removed from the heated zone may not be raised to the required temperature.

Figs. 2 and 3 show a plan and elevation of an arc furnace designed to obviate these difficulties. As before, *A* is the crucible, *D* and *D'* being the electrodes, but D' instead of being connected directly to the crucible as in Fig. 1, is connected by the screw joint with a graphite brick or plate *B*. The crucible is thus in electrical connection with this electrode *D'* by means of surface contact with *B*, and this has been found amply sufficient, and has the advantage that the connection *D'* and *B* is a fixture, one of these answering for any changes in the crucible which may become necessary. Moreover, if the crucible is to be lifted out for pouring the contents, the operation is easier with a plain crucible without the attached horizontal electrode.

The crucible itself differs from the preceding one, in that at the bottom is placed a graphite plug *E*, raised about 20 mm. above the bottom. The arc is then struck from the vetical electrode *D* to this plug, and continues in this way throughout the run. Thus the charge *C* is heated by the radiant heat from the arc, and is not subjected to its direct action as was the case in Fig. 1.

The result is that the charge after a time becomes evenly heated to the required temperature, giving a better product of higher yield. A temperature of 2,000° C. may be maintained at the charge space, using a current of about 350 amps. at 35 volts drop across the furnace. This figure was determined by an optical pyrometer sighting through a graphite tube, the end of which was placed in the position occupied by the charge.

The crucible is protected by lime *G*, supported by the brick retaining walls *H*, the mouth being covered by any suitable material. For this purpose a carborundum wheel broken in half will be found suitable, and should the temperature be so high that this is melted, graphite plates can be substituted.

Thus the furnace consists essentially of a Moissan furnace of graphite, arranged vertically, with the advantages of greater ease of construction, and in which the charge is brought nearer to the source of heat.

Electrochemical Laboratory,
Department of Chemistry,
Columbia University.

American Society for Testing Materials.

The annual convention of the American Society for Testing Materials was held from June 21 to 23 at Atlantic City, N. J. The Iron and Steel section held three sessions, in which a large amount of business was transacted and numerous excellent papers were presented. Concise abstracts of all of them will be given in our Synopsis in our next issue.

The important subject of specifications for steel rails was again thoroughly discussed, but no progress can be recorded, since the whole matter was again referred to the committee A for further consideration. The trouble is that the rail manufacturers and the railway engineers within the committee cannot reach an agreement on several important points.

The report of committee O on uniform speed in commercial tests recommends that speeds of 6 inches per minute for boiler and bar specimens (8-inch testing length), and 3 inches per minute for forging specimens (2-inch testing length), be considered maxima; below these values speed has no influence on ultimate strength and elongation. The determination of elastic limit should be made at a low speed, say ½ to ¾ inch per minute.

The heat treatment of steel and the corrosion of iron and steel were also the subject of extended discussion. These will be dealt with in our next issue.

Electric Smelting of Iron Ore.

Dr. Eugene Haanel's official "preliminary report on the experiments made at Sault Ste. Marie, Ont., under the Canadian Government auspices, on the smelting of Canadian iron ores by the electrothermic process," has just been made public. Since the chief results of these tests have already been covered in an illustrated article in our April issue (page 124), we abstract from Dr. Haanel's report only those parts which contain new information.

CONSTRUCTION OF FURNACE.

The electric furnace was designed by Dr. Paul L. T. Héroult. It is shown in the adjoining diagram.

The furnace consisted of an iron casing bolted to a bottom plate of cast iron, 48 inches in diameter. The casing was made in two cylindrical sections, to facilitate repairs. To render the inductance as small as possible, the lines of magnetic force in the iron case were prevented from closing by the replacement of a vertical strip of 10 inches width of the casing by a copper plate. Carbon paste was rammed into the lower part of the furnace up to the bottom of the crucible. The lining consisted of common fire-brick, which from the bottom of the crucible up for a distance a little above the slag level was covered with carbon paste to a thickness of a few inches. The crucible, therefore, consisted entirely of carbon.

The lining of the furnace was given the shape of a double cone set base to base. Changes in the dimensions of the interior were made from time to time, as indicated by experience, but for the majority of the experiments they were as follows:

	Inches.
Diameter of bottom of crucible.....	24
Height of lower cone.....	11
Height of upper cone.....	33
Diameter of joint base of the two cones.....	32
Diameter at top of furnace.....	30

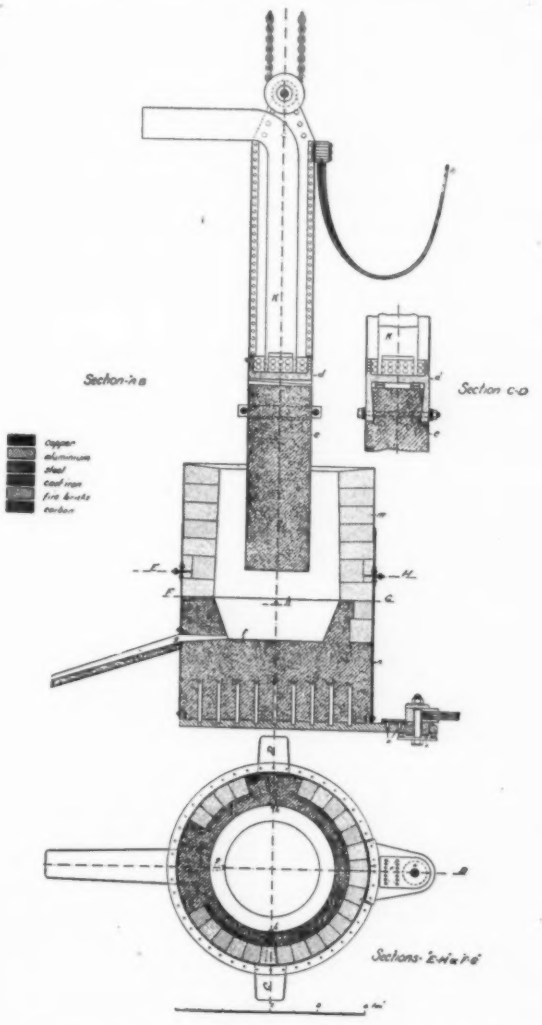
The electrodes, manufactured by the Héroult process (which is kept secret) and imported from Sweden, were prisms of square cross-section, 16 x 16 inches by 6 feet long. The contact with the cables carrying the electric current to the electrode consisted of a steel shoe riveted to four copper plates, which ended in a support for a pulley. The electrode with its contact was supported by a chain passing under the pulley, one end of the chain being fastened to the wall, the other end passing over a winch operated by a worm and worm-wheel. This formed a convenient arrangement for regulating the electrode by hand.

The electrical energy was furnished by one phase of a three-phase, 400-kw., 30-cycle, 2,400-volt alternator. Current was supplied at 2,200 volts to a 225-kw. oil-cooled transformer, which lowered the voltage to 50. The transformer was placed in a separate room in the furnace building, close to the furnace. From the transformer the current was led to the bottom plate contact of the furnace, and to the electrode contact by conductors, consisting each of thirty aluminium cables, 5/8 inch in diameter.

EXPERIMENTS.

A number of experiments required to be made to adjust the capacity of the crucible of the furnace to the energy available, and to determine the shape to be given to the interior of the furnace, to insure easy passage of the charge into the reducing and melting zones. After this attempts were made to utilize the calorific energy[1] of the carbon monoxide resulting from the reduction of the ore, which in all experiments so far recorded had been wasted. To accomplish this, air under pressure was introduced into the furnace about 12 inches below the upper level of the charge. The carbon of the charge, in the form of coke dust, was mixed with fire-clay, and briquetted to prevent it from being consumed by the air blast. It was hoped that by thus utilizing the carbon monoxide in preheating the charge and partially reducing the ore, the output would be materially increased.

It was found, however, that the great heat evolved by the combustion of the carbon monoxide caused the charge to become sticky and to hang. Nor could this be remedied by stoking, the space between the walls of the furnace and the



SECTIONS OF HEROULT ELECTRIC FURNACE FOR IRON ORE REDUCTION.

electrode being too narrow. Moreover, the electrode, although it had been protected with asbestos and iron sheeting, was found after the experiment to have been badly corroded. The furnace was not at all adapted for these experiments, and further attempts in this direction were abandoned. The experiments, however, showed that with a differently constructed furnace, in which the electrode is isolated from the charge, the output might be greatly increased by the introduction of an air blast.

SMELTING OF MAGNETITE.

Magnetite is the chief ore, and is to some extent a conductor of electricity. It was expected that considerable difficulty

[1] See the patent of Héroult, on page 152 of our April issue, and the editorial discussion on page 165 of our May issue. It will be seen, however, that the procedure at the Soo was different from the process as patented, since in the latter the carbon is introduced through the hollow electrode separately from the ore.—Editor.

would be experienced in the smelting of magnetite on account of its conductivity. It was thought that with the furnace in use, in which the electrode was immersed in the charge, the current would disseminate itself laterally from the sides of the electrode through the charge, preventing the current at the reducing and fusion zone from attaining such density as would be required for the high temperature necessary for reduction and fusion. With charcoal as a reducing agent no difficulty was experienced in this respect, nor was the inductance of the furnace increased by the presence of magnetite.

Charcoal can be cheaply made from mill refuse and other sources of wood supply useless for other purposes. Charcoal and peat-coke constitute home products in the provinces of Ontario and Quebec, while coal-coke must be imported. No difficulty whatever was experienced with charcoal as reducing agent, without being briquetted with the ore. "In fact, so admirably adapted was charcoal, when crushed to pass a ¾-inch ring, as a reducing agent in the electric furnace, that coke and briquettes of coke with clay were abandoned, and all the experiments with magnetite and roasted pyrrhotite were made with charcoal." Some of the charcoal available was of very poor quality, some of it being little better than charred wood, containing only about 56 per cent of fixed carbon. ("This and the fact that a considerable quantity of the charcoal was consumed on top of the furnace, account for the large quantity of charcoal used per ton of product. A modification of the furnace, protecting the upper layer of the charge from the atmosphere, and the use of charcoal properly carbonized, would decrease considerably the amount of charcoal which was actually used in the experiments, and consequently reduce the cost of production.")

The following is a record of one run ("No. 14" in the report), in which magnetite from the Blairton mine was treated with charcoal as reducing agent and limestone and sand as flux:

Analysis of raw materials:

Blairton ore—6.60 per cent SiO_2, 60.74 Fe_2O_3, 17.18 FeO (55.85 Fe), 1.48 Al_2O_3, 2.84 CaO, 5.50 MgO, 0.037 P_2O_5 (0.016 P), 0.57 S, 5.053 CO_2, and undetermined.

Charcoal—14.06 per cent moisture, 28.08 volatile matter, 55.90 fixed carbon, 2.54 ash.

Limestone—1.71 per cent SiO_2, 0.81 Fe_2O_3 + Al_2O_3, 92.85 $CaCO_3$, 4.40 $MgCO_3$, 0.004 P, 0.052 S.

The sand used was common furnace sand, of which no analysis was made.

Composition of charge—400 pounds ore, 125 pounds charcoal, 25 pounds limestone, 6 pounds sand.

Analysis of products:

Iron produced ("cast No. 80," grey iron)—Total C 3.73 per cent, Si 3.53, S 0.042, P 0.034.

Slag produced—33.80 per cent SiO_2, 10.20 Al_2O_3, 21.79 CaO, 30.50 MgO, 2.05 S, 0.25 Fe.

Ratio of weight of slag to that of iron = 0.41.
Length of run, 65 hours 30 minutes.
Mean volts on furnace, 36.03.
Mean amperes, 4987.
Power factor, 0.919, hence
Watts 165,125, or electric horse-power, 221.34.
Pig iron produced, 11,989 pounds, hence
Output of pig iron per 1,000 e. p. h. days = 9.92 tons, or
E. h. p. year per ton of pig = 0.276.

Reduction of Sulphur and Production of Ferro-Nickel Pig.

Another important result of the experiments was the fact that ores of high sulphur content, not containing manganese, can be made into pig iron containing only a few thousandths of a per cent of sulphur.

In the following run ("No. 18" of the report) roasted pyrrhotite was treated with charcoal as reducing agent and limestone as flux:

Analysis of raw material:

Roasted pyrrhotite—10.96 per cent SiO_2, 3.31 Al_2O_3, 65.43 Fe_2O_3 (45.80 metallic Fe), 3.92 CaO, 3.53 MgO, 1.56 S, 0.016 P, 0.41 Cu, 2.23 Ni.

Charcoal and limestone same as in previous runs.

The limestone in the charge was decreased from 120 pounds when starting to 50 pounds. The composition then being 400 pounds ore, 110 pounds charcoal, 50 pounds limestone.

Analysis of products:

Iron Produced.	*Cast No.* 125.	*Cast No.* 130.	*Cast No.* 133.
Total C.....	3.23 %	3.38 %	2.50 %
Si ...	4.90[2]	4.50[2]	6.32[2]
S	0.007	0.006	0.007
P ...	0.062	0.037	0.042
Cu ..	0.86	0.87	0.71
Ni ..	3.70	4.12	4.00

Slag produced—16.44 per cent SiO_2, 13.86 Al_2O_3, 53.25 CaO, 8.80 MgO, 5.28 S, 0.65 Fe, traces of Cu and Ni.
Ratio of weight of slag to that of iron = 0.69.
Lenth of run, 56 hours 20 minutes.
Mean volts on furnace, 36.05.
Mean amperes, 5,000.
Power factor, 0.919, hence
Watts 165,649, or e. h. p. = 222.05.
Pig iron produced (ferro-nickel) 7,336 pounds, hence
Output of ferro-nickel pig per 1,000 e. h. p. days = 7.038 tons.
E. h. p. year per ton of pig = 0.389.

On account of the enhanced selling value of the ferro-nickel pig, the furnace has been taken over by the Lake Superior Power Co. for use in commercial operation.[3]

Smelting of Titaniferous Iron Ore.

In the following run ("No. 19" of the report) titaniferous iron ore was treated with charcoal as reducing agent and limestone and fluorspar as flux:

Analysis of raw material:

Titaniferous iron ore—7.12 per cent SiO_2, 30.30 Fe_2O_3, 28.78 FeO (43.59 Fe), 7.00 Al_2O_3, 1.00 CaO, 4.14 MgO, 0.064 P_2O_5 (0.028 P), 0.04 S, 17.82 TiO_2, and 2.50 Cr_2O_3 (1.42 Cr).

Charcoal and limestone as in previous runs.

Composition of charge—400 pounds ore, 100 pounds charcoal, 50 pounds limestone, and 50 pounds fluorspar.

Analysis of Products:

Pig Iron Produced.	*Cast No.* 136.	*Cast No.* 137.
Total C.....	... %	3.50 %
Si	4.50	2.80
S	0.007	0.091
P	0.143	0.060
Ti (appr.).	1.00	1.30

Slag produced—7.00 SiO_2, 28.50 Al_2O_3, 14.23 CaO, 2.93 MgO, 38.92 TiO_2, 1.13 Fe, 0.90 S.

On account of the furnace being in a very bad condition, the lining being eaten away by the limey slag used in the previous run, the run had to be stopped and no figures as to output could be obtained.

The slag was very fluid, and likely the fluorspar in the charge could have been reduced considerably or omitted altogether.

The iron obtained in cast No. 136 was probably mixed with

[2] "By increasing the limestone of the charge the silicon content of the ferro-nickel pig recently produced has been depressed to 2 per cent."

[3] It is reported from a reliable source, although not authoritatively confirmed, that the process pays its way in commercial operation, but would be made far more remunerative by increasing the capacity, since the cost of attendance is comparatively high for the size of furnace (which was originally intended for the experimental work only). With an increase of capacity of furnace, the cost of attendance would not be materially raised.—Editor.

some iron from the previous charge, when ore with high phosphorus content was used.

"This experiment made with a titaniferous iron ore containing 17.82 per cent of titanic acid permits the conclusion that titaniferous iron ores up to perhaps 5 per cent titanic acid can be successfully treated by the electric process."

GENERAL REMARKS.

The ores treated, with the exception of the hematite and the roasted pyrrhotite, contained a high percentage of magnesia, producing a very infusible slag. When the furnace had been running for some time this infusible material formed a scale around the crucible, the electric energy available not being sufficient to keep it in a molten condition. The crucible and lower part of the furnace were, therefore, partially filled up, preventing easy access of the charge to the reducing and melting zone. This slower feeding left the charcoal on top of the furnace exposed to the air a longer time, thus increasing the amount of charcoal required and decreasing the output. With a greater current than was available and consequent higher temperature, the formation of the scale would have been prevented, and the output correspondingly increased.

The electric installation at the disposal of the experimenters was far from ideal for electric smelting experiments. Aside from the drop of voltage, due to the frequent slipping of the belt connecting motor and generator, it was impossible to increase the current beyond 5,000 amps. at from 35 to 40 volts.

This inelasticity of the system prevented the determination of the most suitable current and voltage for a given charge in the furnace.

CONSUMPTION OF ELECTRODE.

For the production of 42,711 pounds of pig iron 384 pounds of electrode were consumed, the same electrode having been in commission for thirteen days.

The consumption of electrode per ton (2,000 pounds) of pig iron was, therefore, 17.98 pounds.

During the time this electrode was in commission the material in the furnace was melted down several times, exposing the red-hot electrode to the oxidizing atmosphere. The consumption of electrode was found to be greater for white iron than for grey iron, and since the 42,711 pounds of pig iron produced included several casts of white iron, the consumption of electrode was also on that account greater than it would have been had only grey iron been produced.

MODIFICATION OF EXPERIMENTAL FURNACE FOR COMMERCIAL PRODUCTION OF PIG IRON.

Probably the largest unit which can at present be constructed on the model of the experimental furnace will not exceed 1,500 hp. The construction of the experimental furnace to fit it for the production of pig iron on a commercial scale will require to be modified in the following important particulars:

(1) The top of the furnace requires to be modified to permit of the application of labor-saving machinery for charging.

(2) Provision requires to be made for the collection and utilization of the carbon monoxide produced by the reduction of the ore; this involves also the protection of the charcoal of the charge from combustion on top of the furnace.

The greater capacity insuring less loss of heat by radiation and the modification of the furnace to permit of the utilization of the carbon monoxide, will materially increase the output beyond that ascertained by the experimental furnace. The experiments indicated that under *normal* conditions about 11.5 tons were produced by an expenditure of 1,000 e. h. p. days.[4] It is, therefore, not unreasonable to assume that under similar conditions with a properly constructed plant the output per 1,000 e. h. p. days would certainly reach 12 tons. This figure has been adopted in calculating cost of production per ton of pig.

The protection of the charcoal of the charge from combustion on top of the furnace will materially decrease the amount of charcoal necessary for reduction and consequently lessen the cost of this item. This saving has, however, not been taken into account in the estimate of cost.

ESTIMATE FOR 10,000-HP. PLANT.

The following estimate for a 10,000-hp. plant, producing 120 tons of pig iron per day of 24 hours, is given in the report on the authority of Dr. Paul L. T. Héroult:

Furnaces, contacts, overhead work	$24,500
Bins, chutes, elevators	14,000
Crushers	4,000
Hoists and regulators	10,500
Instruments	1,400
Cables for conductors	8,400
Building	10,500
Mixer and casting machine	10,000
Traveling crane and tracks	5,000
Ladles	1,500
Slag trucks	3,000
Ore bins	3,000
Repair shop	5,000
	$100,800
Charcoal plant	50,000
Power plant (assuming cost of developing 1 e. h. p. = $50,00)[5]	500,000
	$650,800
Electrode plant	6,000
Unforeseen expenditure	43,200
	$700,000

[4] This figure is the same as was given by us on page 126 of our April issue, on the authority of Dr. Héroult. It may also be expressed in the form that 1 ton (2,000 lbs.) of pig iron produced requires 83 hp-days. In the commission report of two years ago (our vol. II., page 484) Mr. Harbord gave the figure 128 hp-days per ton, of course, on the basis of experiments made in a cruder and more experimental furnace. Dr. Héroult emphasizes that the figure of 83 hp-days per ton of pig iron is a safe figure and represents the upper limit of electrical energy consumption in a properly constructed commercial electric furnace. If the carbon monoxide is burned to dioxide within the furnace itself, the energy consumption would be considerably reduced. The theoretical thermochemical data on this point may be found in our analysis of Dr. Héroult's corresponding patent, on page 152 of our April issue. According to Héroult, the production of 1 kw of iron requires 200 grams of carbon and 1 electric hp-hour (an allowance being made in this estimate for losses by radiation and for heat escaping with the gases). This may, for the present, be considered as the lower (theoretical) limit of fuel and energy consumption. One e. hp-hour per kg iron is equivalent to 38 hp-days per ton of 2,000 lbs. of iron.—Editor.

[5] Concerning this point, which is of most fundamental importance, reference may be made to the very conservative figures of Dr. Louis Bell on the cost of power generation for electrochemical works, our vol. II., page 301. The cost of developing hydraulic power varies enormously according to local conditions. "In any region where electrochemical work is likely to be carried on, hydraulic rights have to be purchased at prices varying from, say $5 to $25 per horse-power, available throughout the year. Then comes the work of development, building dam and canal, blasting and dredging, building roads and retaining walls and power house and setting wheels. The total is most uncertain—almost anything from $25 or so per horse-power to $100 or more. The latter figure would be too large for serious consideration in connection with electrochemical work, and the smaller requires a rare combination of good fortune and low prices." The total cost of the electric generator and transformer plant is given by Dr. Bell as running "from $15 to $25 per kilowatt capacity of plant, reaching the lower limit only in large work under very favorable conditions." The figures of $15 to $25 per kilowatt are equivalent to $11.25 to $18.75 per horse-power. Hence, if there is no transmission line, the total cost, according to Dr. Bell, will vary between about $36 to $119 per horse-power, so that Dr. Héroult's figure of $50 is within these limits. In an article in our vol. II., page 421, Mr. Louis Simpson thinks that Dr. Bell's figures are too high, and that for an electrometallurgical plant the cost of developing one electric horse-power may not be more than $40.—Editor.

Amortization	5%	
Depreciation	5%	15% on $700,000 = $105,000.
Interest	5%	
On a production of 43,200 tons per year of 360 days per ton of pig iron		$2.43

Cost of Production Per Ton Pig Iron.

Ore (55% metallic iron) at $1.50 per ton	$2.70
Charcoal, ½ ton, at $6.00 per ton	3.00
Electric energy, amortization, etc	2.43
Labor	1.00
Limestone	0.20
18 pounds of electrode at 2 cents per pound	0.36
General expenses	1.00
Total	$10.69

Dr Haanel's report is designated as a "preliminary" one, so that a report, giving in detail all records of all tests made, is presumably to be issued later on. However, the present preliminary report appears to contain everything that is essential. Undoubtedly the results of the tests at the Soo have furnished us with important figures, on the basis of which it may be safely estimated in any special case, whether or not electric smelting of iron ore can be economically carried out in a given locality.

* * * *

Since the above report marks in a certain way the end of what may be considered as the experimental epoch of the electrometallurgy of iron and steel, a concise summary of what has or has not been accomplished seems now in order. We will try to classify somewhat the vast amount of information which has been formerly published in our columns on this subject. In the following references to articles published in this journal the Roman figure represents the volume, the Arabic figure the page.

Manufacture of ferro-alloys.—For making high percentage ferro-alloys the electric furnace now reigns supreme, especially in the manufacture of those ferros in which a highly refractory oxide (like that of titanium) is to be reduced. For this problem the electric furnace is superior to the blast furnace simply on account of the higher temperature available. The chief technical problem is to keep the carbon content down. See the summary of Scholl, II., 349, 395, 449; processes of Rossi, I., 523, III., 322, 362; Héroult, I., 467, III., 155; Gin, I., 131, II., 149, 324; Sjostedt, I., 353, II., 153, 188, 207, IV., 128; de Alzugaray, II., 430; Stewart and Kuegelgen, II., 468, IV., 32; Price, III., 170, 171; Vielhomme, III., 362; other notes and articles on ferro-alloys, I., 105, 583; II., 65, 122, 145, 199, 318; III., 79, 84, 120, 133, 168, 210, 226, 254, 423, 448, 459; IV., 195, 247.

Manufacture of high-grade steel.—The electric furnace seems to be destined to gradually replace the crucible steel process. The advantages of the electric furnace are lower cost of operation, due to larger units and consequently smaller labor charge per ton of output and greater durability of the electric furnace. The cost of electric power is a comparatively small item in this case, and becomes almost insignificant if fluid steel is supplied from an open-hearth furnace or from a Bessemer converter to an electric furnace for refining. It is likely that steel which has been refined in the electric furnace at a small cost, may be used in future to a much greater extent than is now possible with the high price of crucible steel. In this case electric steel will cover a broader field than is now covered by crucible steel. An impartial and authoritative statement of the situation in 1904 was given in the report of the Canadian Commission, visiting Europe (II., 479), Dr. Hannel being chairman. Of the numerous processes which have been proposed, tried and tested, at least two are now in successful operation in this country; the Héroult process in a 50-ton per day electric furnace at the plant of the Halcomb Steel Co., in Syracuse (III., 338, IV., 164) and the Colby induction furnace at the Tacony works of Henry Diston & Sons, near Philadelphia (capacity 200 pounds of steel). See concerning process of Héroult, I., 63, 287, 449, II., 408, 481, III., 156, 337, IV., 31; Keller (similar to Héroult), I., 162, 420, IV., 167; Colby induction furnace, III., 134, 299, 341, 373; Kjellin induction furnace, I., 70, 141, 283, 376, 526, 576, II., 479, III., 294, 395, 432, 481; Schneider induction furnace, II., 283, 323, III., 156; Gin, II., 20, III.; 372, IV., 167; Girod, II., 309, III., 434; Stassano, III., 391, IV., 167; Minet-Neuburger, II., 369; Gerard, III., 111. Concerning the subject in general see also I., 462; II., 475; III., 311.

Reduction of iron from ore.—The above report of Dr. Haanel and our preliminary notes on the Soo experiments (III., 447; IV., 84, 124, 164) contain the best information now available on the question as to the special conditions which would render an electric furnace equal or superior to the blast furnace. See also the report of Goldschmidt on the Stassano furnace, I., 247, and the report of the Canadian Commission, visiting Europe, II., 483; also I., 277, 336, 397; III., 53. Furnace designs: Héroult's, I., 467 and above report; Keller, I., 420, II., 483, IV., 167; Harmet, I., 422, 587, 588, II., 110, 503; Stassano, I., 247, 461, III., 391; Conley, I., 426, II., 424; Lodyguine, III., 178; Gerard, III., 111; Contardo, I., 63, II., 110.

Various special applications of the electric furnace in iron and steel metallurgy.—Steel mixer, Héroult, IV., 30. Use of electric heat in combination with open-hearth furnace for taking off the peak of the load, Richards, II., 178. Fritting together of iron concentrates from magnetic separators, Ruthenburg, I., 58, 84, 202, 482, 494, II., 315, 486, III., 416, 481, IV., 238. Treatment of New Zealand iron sands, Galbraith III., 112, 344, 346. Treatment of black sands of Pacific coast, Day, III., 445, IV., 4. General articles on electrometallurgy of iron and steel, Goldschmidt, I., 461; Bennie, II., 307; Neumann, II., 488; Canadian Commission report, II., 475, 479.

The Lines of Current in Storage Batteries—An Experimental Study.

By M. U. Schoop.

While our knowledge of the distribution of the lines of current in metallic conductors and of the distribution of the lines of force in a magnetic field is relatively perfect, we are much less informed on the distribution of the lines of current in electrolytes and on the true current-density at different points of an electrode surface. This is indicated by the lack of literature on this subject.

As an interesting contribution to this subject, I may first mention an investigation by A. Tribe,[1] who placed small longitudinal intermediate electrodes at different points of the electrolyte. The deposit obtained on each intermediate electrode was taken as an indication of the electric conditions at that point. Since they act as bipolar electrodes, polarization currents must result between the two sides of the electrode so that this method is not suitable to give an exact picture of the "electrolytic field." J. Stark[2] studied in great detail the path which the current takes if a small electrode is placed between the main electrodes, whereby the original metal forming the auxiliary electrode produces local currents with the electrolytic deposit.

Of great interest is, finally, an investigation of Dr. K. Norden[3]. The difference in current density at different points of an electrode was rendered by him directly visible by the qualitative change of the deposit from a mixture of solutions of copper sulphate and zinc sulphate upon an intermediate electrode. On the supposition that the intermediate electrode is perfectly parallel to the main electrodes and fills the cross-section of the electrolyte as perfectly as possible, the differences

[1] Phil. Mag., 1881, page 446.
[2] Wiedmann's Annalen, 1898, page 245.
[3] Paper read before the annual convention of the German Electrochemical Society, in Zurich, 1900. See Zeit. f. Elektrochemie, 1900.

in the current density at different points of the electrode are indicated directly by the color of the deposit, since the color changes with the proportion of the copper to the zinc in the deposit.

In the following I will describe a method which permits to study, with relatively simple means, the distribution of the lines of current in electrolytes with sufficient exactness for all practical purposes. I have described this method in a paper read on May 18, 1906, before the French Physical Society in Paris.

I.

If we pass a current through an electrolyte between two electrodes, the lines of current will not be held together so as to have the shortest possible length. On the contrary, the lines of current will always fill the whole space filled with the electrolyte. The relation which is valid for metallic wires, namely, $R = c \frac{l}{q}$ where R is the resistance, l the length, q the cross-section and c the resistivity of the wire, can be used directly for electrolytes only under the supposition that there is no straying of lines of force. For instance, in the special case in which the electrolyte is enclosed in a cylindrical tube, which is closed at both ends by electrode surfaces, having uniform conductivity all over their area, the lines of current may be assumed to pass uniformly in straight lines through the electrolyte from one end to the other.

In all other cases there is a straying of lines of current whereby the length of the lines of current from one electrode to the other electrode is increased, while the cross-section (or the number of ions transporting the current) is also increased. The increase in the length of the lines of current raises the resistance, while the increase of cross-section diminishes the resistance. As may be easily shown by an experiment, the latter effect is predominant, so that the total resistance is diminished. It is, therefore, possible to state the law in this form: The ions which transmit the electricity do not choose the geometrically shortest way, but the electrically shortest way (that is, the path of least total electrical resistance).

It is true that the influence of the electrolytic "shunt current" on the distribution of the lines of current and on the current density on the electrode surfaces must be smaller the

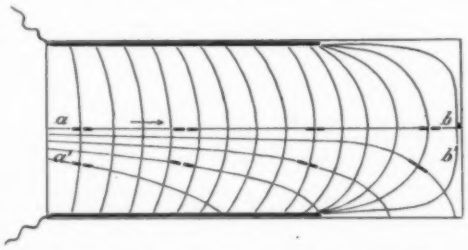


FIG. 1.—TEST OF STRAYING OF LINES OF CURRENT.

nearer the electrodes are together. One might, therefore, think that this effect is insignificant in storage batteries, when the distances between plates are, as usual, between 3 and 15 mm. This assumption, however, would be wrong, as we shall see later on.

In the determination of the distribution of lines of current in storage batteries, two different problems should be distinguished; namely, *first*, what is the distribution of the current in the electrolyte under the assumptions that there is no drop of voltage in each electrode itself (which are, therefore, assumed to be of infinitely high conductivity), and that the conductivity of the electrolyte is uniform throughout? *Second*, what is the current density at different points of the electrode surface, and how is the distribution of the lines of current affected by the voltage drop in the electrodes, by the non-uniform conductivity of the electrolyte and by the straying of the lines of current (*i. e.*, by the electrolytic "shunt current")?

The first problem may be easily solved by the following simple experiment: In a long vessel of celluloid, two bright sheets of lead are placed, as indicated in Fig. 1. The influence of non-uniform acid density and concentration is eliminated in this arrangement. The sheets are placed directly on the walls of the vessel, but it is preferable to provide their inside surface (which is attached to the wall) with a coating of insulating paint. I found celluloid paint quite useful, made by dissolving pieces of celluloid in amyl acetate.

From a very thin, spongy lead plate two small rectangular pieces are then cut out and combined in form of the little instrument shown in Fig. 2, which is called the "analyzer." Since the distribution of the lines of current in the electrolyte should not be changed by the analyzer, the dimensions of the two rectangular electrodes should be chosen as small as possible, and the little glass tubes containing the two wires which lead to the two electrodes should also be small. These two wires are connected with a Weston millivoltmeter or a suitable sensitive galvanometer.

The analyzer is then placed in the electrolyte and turned around its axle of symmetry until the voltmeter no longer gives any deflection. The two electrodes of the analyzer are then on an equipotential surface, and the lines of current are perpendicular to it. If it is thought that it is not possible to turn the analyzer with sufficient exactness by hand, a frame may be used along which the analyzer may be displaced.

FIG. 2. ANALYZER.

The millivoltmeter gives zero deflection if the analyzer is displaced, for instance, along the line *a b* in the center of the vessel, Fig. 1, the analyzer being moved as indicated by the arrow. In this case the analyzer electrodes are parallel to the two main electrodes and are at equal distance from both.

If the same experiment is repeated, but starting from a point nearer to one main electrode than the other, then the analyzer must be turned more to one side, the further it is passed along the vessel. In this way the equipotential curves shown in Fig. 1 are obtained. By plotting in the diagram curves which are at every point perpendicular on the equipotential curves one gets the lines of current which are also shown in Fig. 1.

If one wants to avoid the formation of gas, which always occurs with lead plates, the latter may be replaced by fresh accumulator plates, but it is to be remarked that in this case a symmetrical distribution of current over the electrode surfaces (*i. e.*, equal current density at all points) is no longer guaranteed, since the conductivity of the active material, especially with spongy lead plates, may not be at all uniform all over the plate.

The lines of current, shown in Fig. 3, were obtained with two bright lead plates. This figure is only intended to indicate the course of the lines of current and of the equipotential lines, and not to give quantitative information on the distribution of the current in the electrolyte or the distribution of the current density over the electrodes.

The distortion of the lines of current, which is the greater the nearer one gets to the right-hand end of the vessel, is clearly shown. If an insulating wall would be inserted from *b* to *b'* all lines of current would be straight lines perpendicular to the two electrodes. If this insulating wall would be inserted in the manner indicated by C in Fig. 3, another distortion of the lines of current would result on account of the electrolytic shunt circuit being cut up.

One of the first experiments which I made in order to get an exact picture of the lines of current in electrolytes was as follows: A horizontal tray, such as used for photographic purposes, was filled with hot paraffine to a height of 4 mm. When this layer of paraffine had solidified dilute sulphuric acid was poured onto it. As analyzer I used in this case two plati-

num wires in form of a fork at the end of a glass tube, connected with the terminals of a telephone. In this case alternating current was, of course, used, or a pulsating current produced by superposing alternating current on the direct current. The analyzer was revolved until the sound in the telephone became a minimum. Then the two platinum points were pressed into the paraffine. In this way dots were obtained in the paraffine, giving directly the equipotential curves.

If one wants to make the experiment in a somewhat more exact way, a tray of hardwood with perpendicular walls should be used, as shown in Fig. 4, two strong nails being symmetrically arranged at both ends and connected to the terminals of the current. By means of an insulating thread around one nail and around the analyzer, the latter is conducted around the nail in a circle.

This experiment is evidently analogous to the classical fundamental experiment of Kirchhoff on the distribution of the lines of current on metallic surfaces (Poggendorf's *Annalen*, Vol. 64, p. 497, 1845). I might mention, however, that I was led to this possibility of determining the distribution of the lines of current in electrolytes by a personal observation, which induced me to study the subject in greater detail for several months.

This observation was made by me while I experimented on alternating-current electrolysis. While putting two fingers into the electrolyte, I found the physiological effect to be more or less evident, or to disappear altogether according to the

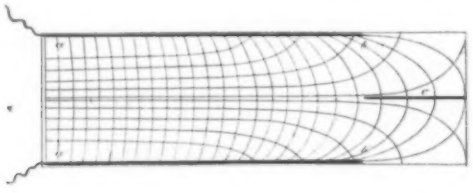


FIG. 3.—LINES OF CURRENT AND EQUIPOTENTIAL CURVES.

position of the fingers in the electrolyte. This position determined, of course, the voltage difference between the two fingers.

If an electrolyte of poor conductivity is used with a strong current, the index finger and the middle finger may be used as a good automatic indicator, since the fingers have a natural tendency to get as quickly as possible into the equipotential line (if they do not jump quickly out of the electrolyte altogether). Little fishes also assume immediately a position along an equipotential surface, so that no current can pass through them. Since fishes are very sensible toward electrical effects a very small voltage should be used. With a 110-volt supply they die immediately.

Against the use of electrode plates the objection may be made that the original distribution of the lines of current can be changed by the introduction of the electrode plates into the electrolyte, and further that polarization may occur. But this objection is no longer valid for the use of the alternating current and telephone, since the dimensions of the analyzer with the platinum wires may be made so small that an effect on the distribution of the lines of current is rendered practically impossible. An influence of polarization phenomena on the result is also practically excluded.

With the telephone it can be conclusively proven that everywhere where there is electrolyte there are also lines of current. For this experiment a high beaker may be placed between two electrodes in a larger vessel, the experiment being arranged as shown in Fig. 5. This apparatus can be easily put up with simple means, and is also quite suitable for some other experiments on the distribution of lines of current in the electrolytes.

On a brass rod *a* two U-formed glass tubes are fastened, through which the two wires *c c* pass, which are connected to the electrodes of the analyzer. By means of these wires the analyzer may be raised or lowered. The glass tube of the analyzer, containing the two wires, should be filled with paraffine, and the two terminals should consist of two small plates instead of points. By means of this apparatus it can be easily shown that as long as the analyzer plates are parallel to the main electrodes, hence perpendicular to the lines of current, it is impossible to stop the noise in the telephone,

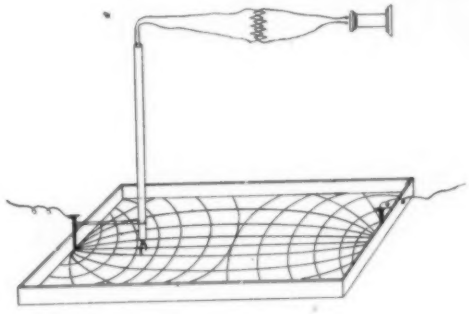


FIG. 4.—SIMPLE ARRANGEMENT OF TEST.

although, of course, the noise gets less and less the more the analyzer is lowered to the bottom of the beaker.

II.

Of equal theoretical and practical importance is the question, how the straying of the lines of current in an electrolyte influences the distribution of the current on the surfaces of the electrodes; *i. e.*, the current density at different points of the electrodes. That there is such an effect we have already seen, the current density increasing at the points of the electrode surfaces near the "electrolytic shunt." For the present we will not consider how the current density on the electrodes is influenced by the manner in which the current enters or leaves the electrodes, or by any lack of uniformity of conductivity over the electrodes or within the electrolyte.

A number of phenomena, well-known from practice, may first be mentioned. With soluble electrodes, with or without stirring, the anode is not uniformly dissolved at all places, but is dissolved more strongly in its lower half, so that when a large part of the electrode has already been dissolved the upper part is often almost unchanged. The same happens even if care is taken to have a good, uniform current supply and efficient circulation.

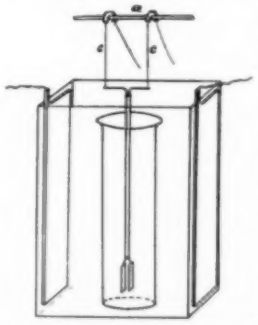


FIG. 5.—PROOF THAT THE LINES OF CURRENT FILL THE WHOLE ELECTROLYTE.

This phenomenon is in agreement with the observation that the loss of capacity in spongy lead plates of storage batteries which have been in use for some time, is greater in the lower parts of the plates than in the upper ones. I once determined the capacity of a spongy lead plate, 210 x 210 x 6 mm., of a stationary storage battery which had been used for three years, and which showed only one-half its original capacity, so that the negatives of this battery (which had been made for a prominent German storage battery factory) had to be replaced. When the plates were carefully examined it was seen that the contraction of the spongy lead was most evident near the lower rim of the plate. I then cut two exactly equal pieces from the lower and upper portions of the plate and determined their capacity separately. I was surprised to find that the upper piece had still 85 per cent of its original capacity, but the lower piece only 40 per

cent. It is probable that the negatives of other makers will show a similar behavior, especially as most stationary types of plates are not of square form (as was the case with the plate which I tested), but are considerably longer than they are broad.

Another observation in connection with this point is that in case of the reversal of a negative plate the brown color always appears first at the bottom. In this experiment it is, of course, necessary to make the cross-section of the electrolyte equal to the surface of the electrode, so that a straying of the lines of current is excluded.

It might be said that the behavior of these negatives is due to the better conductivity of the acid at the bottom than at the top, and that the current density must be higher at the lower parts of the plates than at the upper ones, on account of the smaller resistance of the electrolyte at the bottom.

One has to consider, however, that the difference of concentration of the free acid between the plates at the bottom and top of the cell establishes itself very slowly, and that is very small even with high cells, so that the increase of conductivity, due to the higher concentration at the bottom, is practically negligible, in view of the very flat maximum of the conductivity curve of sulphuric acid. The concentration is rendered again uniform, moreover, by the circulation, due to gasing during charge and due to vibration in automobile batteries.

In the following experiment, the arrangement of which is very similar to that of Fig. 1, the influence of different concentrations and conductivity of the electrolyte is eliminated. In a lengthy celluloid box two bright sheets were inserted, as shown in Fig. 6; the positive one being a copper plate of 1 mm.

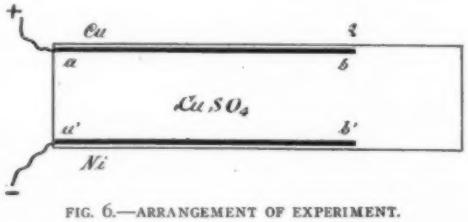


FIG. 6.—ARRANGEMENT OF EXPERIMENT.

and the negative one a nickel plate of ½ mm. thickness. The surfaces with which they were placed against the walls were provided with a coating of insulating paint. Copper sulphate solution was used as electrolyte.

After a current of 5 amps. had been passed through the cell for 24 hours, copper being deposited upon the nickel sheet, the paint was removed and strips about 3 mm. broad were cut off from the four ends of the plates, since small growths like warts had appeared at the rims of the nickel plate. After that strips, 5 mm. broad, were cut off at *a* and *a'* and at *b* and *b'*, and the changes of weight were determined. It was found that the copper strip *b* was lighter by 1.98 gram than the copper strip *a*, and that the nickel strip *b'* was heavier by 1.67 gram than the nickel strip *a'*. If the "electrolytic shunt" had not influenced the current density at the electrodes it is evident that the opposite effect should have been observed, on account of the voltage drop in the electrodes, the current entering at *a*.

The fact that storage battery plates behave differently at the top than at the bottom does not seem to have found much attention in storage battery practice. Very little has apparently been published about it in literature. All I could find in this respect was a note in the book of Dr. P. Schoop, "Die Sekundär Elemente," 2d part, p. 34. It is said there to be peculiar that manufacturers pay so little attention to this matter. "To convince one's self of the defective distribution of current over the surface of plates, for instance, of an older cell of the well-known firm of Pollak & Co., it suffices to observe it carefully during charge in a glass vessel. When gas begins to be set free towards the end of the charge, the gasing first starts only at the upper half of the plates, and only later on the lower half also begins to give off gas when the development of gas has already become strong, whereby the potential in the upper parts has increased. The investigation of English accumulators by Prof. Ayrton, in London, confirms this observation. He found that the active material in the lower half of the plate was always harder than that in the upper parts, on account of a larger content of lead sulphate."

Whoever has had to do in practice with the formation of Plante plates knows how difficult it is to get a homogeneous layer of lead peroxide, especially on large plates, and how easily the phenomena occur which are known in storage battery practice as buckling, etc. These phenomena may be caused by various circumstances, as we will see later on, but it is certain that they are mostly due to the non-uniformity in the current density over the electrodes, due to the "electrolytic shunt." It needs no further proof that a plate which operates with higher current density at the bottom than at the top undergoes larger changes of volume at the bottom, and that a plate which shows differences of change of volume at different points must have a tendency to mechanical distortion and buckling. (*To be concluded.*)

Notes on Electrochemistry and Metallurgy in Great Britain.

(*From Our Special Correspondent.*)

BLAST FURNACE GAS AND POWER DISTRIBUTION.

Concerning the "waste gases" from blast furnaces, the last Royal Commission on Coal Supplies in the United Kingdom reported that these were the only possible untapped source of fuel. It is, therefore, a matter of considerable interest to be able to record that Parliamentary sanction is now being sought to incorporate a company for the purpose of generating electricity and power gas in Cumberland. Lands for generating stations are scheduled at Maryport, Workington and Cleator Moor. The capital of the company will be £450,000, in £5 shares, with borrowing powers to the extent of £150,000.

The objects of the company are to supply electrical energy to authorized undertakers and persons requiring motive power supply, and current to be used for lighting the premises where power is supplied. The Broad of Trade will be referred to in the event of any authorized consumer withholding consent to the company supplying any customer in that area. Authorized undertakers will be required to enter into a seven years' contract, whilst, as in the other power bills, in the event of any dispute as to price between the company and a power user, the Board of Trade will be asked to appoint an arbitrator. Power gas consumers will be asked to enter into a contract for five years. Interest out of capital during construction will be paid at the rate of 3 per cent per annum to the extent of £20,000. Substantial commencement to be made with works within three years, and powers under the bill cease after seven years if a supply is not then given.

The charges for electric supply will be at the rate of 10s. per electrical horse-power, which the company is required to give, and a sliding scale from 3d. to ¾d. per unit, according to quantity. For gas the charge will be 10s. per indicated horse-power, with a sliding scale from 3d. to ¾d. per gas unit.

The only opponents to the scheme were the Whitehaven Corporation, the Workington Urban District Council and the West Cumberland Tramways Co. An agreement has been come to with the Whitehaven Corporation, however, whereby the power company acquires the existing municipal electricity undertaking in that town, the purchase price being £25,000, the capital expended upon it. This purchase is to be completed, in instalments, by March 31, 1910, or sooner if the power company desires. After the completion of the agreement, the company, which will then become the distributors in Whitehaven, is not to charge any higher prices than are now in force. If the purchase is not completed within the period stated in the agreement, all rights of the power company in Whitehaven are to cease.

In giving evidence on behalf of the bill, one of the promotors pointed out that it was proposed to erect three generating stations and to use the waste gases from the blast furnaces in the area, in order to drive gas engines for producing electrical energy. Agreements had been made with the owners of three of the greatest iron works for the supply of such gas for the purposes of the bill. It was estimated that 60,000 hp. were running to waste from the blast furnaces, but half this quantity would be sufficient for the purposes of the bill. It was also intended to supply power gas from the same sources. This was a very suitable gas for compression, and there was no difficulty in its distribution. The Home Office had reported upon the fact that there was no restriction as to the amount of carbon monoxide in the gas, and recommended that a provision limiting this to 14 per cent or such higher percentage as might be approved by the Home Secretary in the interests of the public health. There would be a greater percentage than 14 per cent, but the promoters were willing to place themselves in the hands either of the Home Office or the Board of Trade as to the percentage in the bill.

One can only hope that if Parliamentary sanction is secured the undertaking will be more successful than is so frequently the case with pioneer undertakings.

The Finances of Electrolytic Alkali and Bleach.

The annual report of the directors of the Castner-Kellner Alkali Co., Ltd., for the year ending March 31 last, states that the net profit (after allowances for keeping up works, plant and machinery in a state of efficiency) is £68,847.7.3, added to £12,797.16.11 from 1905, leaving an available balance of £62,548.5.10, and the directors recommend that £30,000 be appropriated to depreciation reserve, and that a dividend at the rate of 8 per cent be paid for six months to March 31 (making 6 per cent for the year), leaving £14,548.5.10 to be carried forward. The directors have increased a part of the company's plant, and have obtained suitable premises at Wallsend-on-Tyne, where the necessary electric power will be supplied on advantageous terms.

"Unsolved Problems in Metallurgy."

Taking the title of this paragraph as his subject, Mr. R. A. Hadfield delivered, on May 3 last, the fourteenth "James Forrest Lecture" at the Institution of Civil Engineers. For a day or so after the lecture I felt a little wonderment at the choice of the title, and questioned its appositeness to the lengthy subject matter which had interested a large audience. Point by point, Mr. Hadfield had reviewed the whole field of the metallurgy of iron, and described the latest achievements in each sphere. Led away perhaps by the wonder and magnitude of these achievements, I failed at the outset to grasp the unwritten moral of the whole lecture, and that was that finality was disclosed in none of the directions mentioned, and that in its ultimate sense all the many and complex problems were in a certain sense unsolved.

Unsolved, that is to say, because limits to improvements are unknown in regard to each of these, and because the explanations and theories of the physicist are only hypotheses and explanations based on present knowledge, and can take little account of future discoveries.

Mr. Hadfield's review naturally touched upon the influence of alloys, heat treatment, pyrometry, the future of electric furnaces, methods of testing and their value, micrography and so forth.

At the conclusion there was an adjournment to the reading room downstairs, where impact tests and analyses and pyrometers were shown in operation. The casual non-metallurgical engineer probably observed the microstructure of iron and steel for the first time under a microscope. The electrical engineer handled Heusler alloys, and then listened to brother civil engineers (whose early training had not embraced modern physics as concerned with magnetism), asking curious questions about an Ewing hysteresis tester.

All watched various liquid air experiments as affecting the magnetic properties and brittleness of certain alloys. When the audience had thinned down an opportunity presented itself of personally asking Mr. Hadfield whether liquid air treatment offered any immediate commercial possibilities. The reply was: "To-day, or this week, perhaps not. As to next year, one cannot say. All precedent is against prophecy in a negative sense. What is a scientific curiosity one year very often, by some sudden demand or improvement in a parallel field, becomes everyday practice next year. There are so many cases which might be cited as examples. Therefore, while to-day no demand or useful service arises, matters may be very different next year."

Market Quotations During May.

The chief feature of the month was the amazing price reached by tin. Commencing on May 1 at a shade over £183, the price mounted from day to day, and under the influences of a heavy home demand and a decline in the visible supply, reached £215 for cash and £205 for three months' delivery by May 14. The rising wave then receded almost as suddenly as it had risen, and fell to £185 within a week. A slight further fall took place, but this was followed by a recovery; finally tin closed at £185 per ton. At this price considerable attention is being given to Cornish mining properties, and several mines have been reopened.

Copper commenced by falling from £85 to £83.5 per ton. The closing price on May 30 was £85.17.6 cash. The present indications seem to point to a continuance of prices above the price of £80 per ton. As regards iron, Cleveland warrants have remained fairly steady, demand and supply balancing fairly closely. There was a rise from 50s. to 51s. in the middle of the month, with subsequent lower quotations at 49s. 11d. Lead has advanced from £16.2.6 to £16.7.6. Zinc sheets have risen to £32. Copper sulphate is fetching £25.15.

In the chemical trades very little changes have to be recorded. Ammonia sulphate is 2s. 6d easier at £12.2.6 per ton. The coal tar derivatives are fractionally cheaper, but the alkaline poducts are unchanged. Shellac has closed at £9.11 per cwt., and I hear of a virtual cornering in the supply.

The Van't Hoff-Raoult Formula.

The Van't Hoff-Raoult formula which is at the bottom of the whole modern theory of solutions, is the subject of a most interesting critical essay of Dr. Wilder D. Bancroft in the May issue of the *Journal of Physical Chemistry*. This paper, which should be studied carefully by all interested in the theory, brings out some very important points as summed up by the author as follows: The osmotic pressure varies with the heat of dilution. The abnormal molecular weights for sodium in mercury, sulphuric acid in water, resorcinol in alcohol, cupric chloride in water, and alcohol in benzene are due wholly or in part to the heats of dilution. The abnormal molecular weights for sodium chloride in water are not due to the heat of dilution. The molecular weights at infinite dilution are correct, but all others are in error to a greater or lesser extent. It is probable that a quantitative theory of concentrated solutions can be worked out if we make corrections for the heat of dilution.

This matter is of extreme interest in connection with the persistent and able fight of Dr. L. Kahlenberg against the "orthodox" electrolytic dissociation theory. As Dr. Bancroft points out, Kahlenberg has worked with finite solutions and has found that one must consider the specific nature of solvent and solute. For finite solutions the heat of dilution is a factor and varies with the specific nature of solvent and solute just as Kahlenberg has found. But for infinitely dilute solutions for which the orthodox electrolytic dissociation theory has been mathematically formulated the heat of dilution becomes negligible, and the results are independent of the nature of solvent and solute—within certain limits.

An Electric Furnace for Heating Crucibles.

BY OLIVER P. WATTS, PH. D.

Accounts of the important types of the electric furnace used commercially are of frequent occurrence in the technical and scientific journals, but published data concerning the construction and operation of laboratory furnaces that have proved successful for particular purposes is as yet not abundant. It is the purpose of this paper to describe a type of experimental furnace used in melting on a considerable scale moderately refractory metals, such as iron and chromium.

In an investigation upon the production and properties of electrolytic iron and iron alloys, now being pursued at the University of Wisconsin, under a grant from the Carnegie Institution, it became necessary to secure a means of melting iron with the introduction of a minimum of impurity. From the high temperature required, some form of electric furnace seemed most suitable, and after several months of experimenting with both arc and resistance types, a very simple form of resistance furnace was adopted, and has now been in successful use for several months.

It consists of a rectangular brick box, into which the crucibles are set, crushed carbon shoveled in and packed around them, and the current turned on until the desired temperature is attained. The outside dimensions are: Length, 54 inches; width, 28 inches; height, 26 inches. The height includes a cellular base consisting of two courses of fire-brick set on edge.

As the furnace rests upon a cement floor laid on the ground, this construction affords ample protection, but if the furnace were set upon a table, in any part of which wood were used, it would be necessary to place a solid layer of brick between the two parts of the cellular base, to check radiation to the table.

The inside dimensions are: Length, 40 inches; width, 12½ inches; depth, 9 inches. The capacity of the furnace is 27 crucibles, each 3 inches in diameter and 7 inches high.

The material used in its construction is fire-brick, with a lining of a single layer of magnesite brick. This lining is necessary, as fire-brick is attacked by hot carbon, and is also melted at the temperature usually attained in this furnace. No cement was used in laying the brick, and none is necessary, but it would be advisable where a permanent furnace is desired, to put iron straps around the outside to prevent spreading of the side walls under the influence of repeated expansion and contraction. This will be done when it becomes necessary to rebuild this furnace.

FIG. 1.—VIEW OF ELECTRIC CRUCIBLE FURNACE FOR MELTING PURE IRON.

The method of heating is similar to that of the Acheson graphite furnace, in which the articles to be heated are bedded in a granular resistor with their lengths at right angles to the heating current, but with the difference that the articles—in this case, the crucibles—are placed in a vertical instead of a horizontal position.

Various crucibles were tried, the most satisfactory being that bored out in a lathe from a cylinder of Acheson graphite, and lined with magnesia. The crucibles are arranged in nine transverse rows of three, those of each row being in contact, and set away from the sides of the furnace as far as possible. This leaves a space of 1¼ inches between the rows; this distance may be reduced to ¾ inch and still give good results.

In charging the furnace a layer of the resistor is put in to the depth of an inch, the crucibles set in as described above, and each one covered by a disc of magnesia, and above this a section of graphite ⅜ inches thick—the latter to prevent contact of the granular resistor with the magnesia cover, as grains of carbon have a most unpleasant way of eating holes in magnesia linings. More of the resistor is now added, and when at a depth of 3 inches it is tamped down at the sides and between the rows of crucibles.

FIG. 2.—STARTING DEVICE.

Particular care is taken to tamp the resistor well where it makes contact with the terminals. These consist of bars of graphite 14 x 1 x 3 inches, to carry the current through the furnace wall, and a short bar of the same material set on edge inside the furnace and mortised to the first bar. The remainder of the resistor is added to a depth of ½ inch or more above the tops of the crucibles, a cover of magnesia brick, or better, of thin slabs of magnesia cement, is laid on, and above this a layer of fire-brick. At high temperatures magnesia brick conducts heat much better than fire-brick, hence the value of a layer of the latter as a top to the furnace. Several sheets of asbestos paper laid on top diminish the heat loss. Fig. 1 shows the furnace in operation.

Any furnace with a granular carbon resistor requires for convenient and economical control, a variation in voltage of at least 100 per cent. This furnace is operated from a direct-current dynamo, giving from 65 to 125 volts, but because of interference with other work, it must often be operated at the constant voltage of 110.

For this reason a special device is used in starting the furnace. This is shown in Fig. 2. A slab of graphite, ½ inch thick and 6 inches high, extends across the middle of the furnace, and serves as an auxiliary terminal. Electrical connection is made with this by a bar of graphite 3 x 1 inches in sections, as shown in the illustration.

At the start the two halves of the resistor are connected in parallel; when, through heating the resistance has diminished sufficiently, they are connected in series, and the graphite bar, which carried current into the middle of the furnace, is removed. The slab of graphite, of course, remains in place.

A typical run with this furnace is as follows:

Time. Min.	*Amps.*	*Volts.*	*Kw.*	*Resistance Ohms.*
0	150	125	18.7	0.83
20	300	120	36	0.40
40	400	120	48	0.30
47	600	120	72	0.20
63	600	110	66	0.18
80	630	105	69	0.16
85	500	76	38	0.15
100	550	74	40.7	0.13
Current interrupted for 7 minutes in changing from parallel to series.				
107	200	120	24	0.60
130	250	120	30	0.48
170	300	116	34.8	0.38
220	400	120	48	0.30
250	450	120	54	0.26
265	500	117	58.5	0.23
280	500	111	55.5	0.22
310	510	110	56.1	0.21
340	500	105	52	0.21

Time, 5 hours 33 minutes; kw-hours, 248; average kw., 45; average watts per cubic inch, 10; ohms per inch cube at end of run, 0.538. The heat was sufficient to melt the purest iron obtainable.

The resistor consisted of a mixture of coke, carbon electrodes and graphite. These materials were run through a crusher, and all pieces larger than 5-mesh were removed. At the outset the finest material was also rejected, but later, contrary to orthodox practice, all except the coarse material was retained. To raise the resistance, carborundum was added, with good results.

By thus mixing materials of different resistivities, it is possible to adapt the resistor to any reasonable voltage and form of furnace that may be desired. In this case it is advisable, though not absolutely necessary, to screen the different materials to a fairly uniform size.

Furnaces of this kind have been built for crucibles of 2, 3 and 4 inches diameter, and varying in capacity from two to eight crucibles set in a single row.

The data of a run with one of these smaller furnaces follows:

Inside dimensions, 33 x 4½ x 6 inches.

Capacity 8 crucibles, 3 inches in diameter and 5½ inches high.

Time. Min.	*Amps.*	*Volts.*	*Kw.*	*Resistance in Ohms.*
0	150	107	16	0.71
20	200	110	22	0.55
21	300	110	33	0.37
24	350	110	38.5	0.31*
27	400	110	44	0.27*
35	370	107	40	0.29*
40	430	107	46	0.25
50	480	107	51.4	0.22
65	380	107	40.7	0.28
72	480	80	38.4	0.17
90	440	83	36.5	0.19
110	0	0	...	...

Kw-hours, 60.6; average energy, 33.5 kw.; average watts per cubic inch, 37.6; ohms per inch cube at end of run, 0.173.

This furnace was designed to be operated from a 110-volt circuit, and, as shown above, it was not necessary to throw any resistance into the circuit except for the last 38 minutes. This result was secured by the great length in prpoortion to cross-section of the resistor, and by the liberal addition of carborundum.

In order that the furnace might start at 110 volts, a chain of three carbon rods, ¼ x ⅜-inch in section, was buried in the resistor, and withdrawn only when the latter had become heated sufficiently to take the desired amount of energy. Such use of small carbon rods for regulating the current in granular carbon resistors has been found very convenient.

In operating the large furnace the crucibles were allowed to cool in the furnace, but in some of the smaller furnaces they were not completely buried in the resistor, and were withdrawn for pouring the metal. When the crucibles are removed, the resistor falls into the holes, so that freshly charged crucibles cannot well be set in. As an intermittent furnace has served the purpose, no particular endeavors have been made to render it suitable for continuous operation.

To prevent the removal and introduction of crucibles while the furnace is in operation, FitzGerald (Electrochemical and Metallurgical Industry, February, 1905) has recommended the construction of the resistor of silico-carbides. The writer has tried no experiments for this purpose, but would suggest an outer container of Acheson graphite bedded permanently in a carbon resistor, the crucibles setting loosely in this container. As graphite is such an excellent conductor of heat at high temperatures the added thickness of this material between the resistor and the charge within the crucibles would have but a slight effect upon the operation of the furnace, the only serious consideration being the extra heat needed to bring this additional material to the working temperature of the furnace.

Crucibles of Acheson graphite, 4 inches in diameter, are as readily heated in these furnaces as those of 3 inches diameter, but with the increase in size there is a greater proportion of failures of the magnesia linings.

In the paper by FitzGerald, already referred to, concerning the use of crucibles of Acheson graphite in a granular carbon resistor, he says: "Here we have, unfortunately, a material that is an excellent conductor, for its resistivity is only 0.0008, so that it short circuits the current at the part of the resistor where it lies. In order to get the most satisfactory heating of crucibles of this sort it is necessary to use currents of great amperage, so that a heating effect is obtained by the passage of the current through the walls of the crucible."

That satisfactory heating of crucibles of Acheson graphite can be secured without depending upon the passage of the current through the walls of the crucibles, as the source of heat is conclusively proved by the operation of the furnace described above. In the largest furnace, the area of graphite in crucibles and covers cut by a transverse plane through the furnace varies from 9 to 13 square inches. Five hundred amperes is sufficient to heat this furnace, yet a current 25 per cent greater than this fails to heat to redness in the air a cylinder of Acheson graphite 1½ inches in diameter, having a cross-section of only 1¾ square inches.

It is apparent that the heating effect must be sought elsewhere than in the passage of the current through the crucible walls, and must be mainly due to its passage through those portions of the granular resistor which lie between the rows of crucibles, aided more or less by a high contact resistance between resistor and crucibles.

The high electrical conductivity of Acheson graphite at elevated temperatures indicates a correspondingly great thermal conductivity, and this latter property no doubt contributes greatly to the successful operation of the furnace, the crucibles acting as equalizers of temperature as well as conductors of heat from the resistor to the crucible linings.

At first thought the burying of a crucible in a carbon resistor might seem a most unpromising method of melting metals that one desires to keep free from carbon, but experiment shows that iron and many alloys may be so melted, and contain only 0.01 to 0.05 of 1 per cent carbon.

It has been found that the addition of aluminium, magnesium, or calcium, metals which are capable of reducing carbon monoxide at high temperature, increases the carbon content to several tenths of a per cent. If added in large quantity they would probably introduce considerable amounts

* Starting rods are removed.

of carbon by such reducing action. A similar reaction will probably occur in the arc furnace.

Among the advantages of this resistance furnace for crucibles may be mentioned:

I. Low cost and simplicity of construction.

II. The possibility of designing the furnace to heat any desired number of crucibles simultaneously.

III. By adapting the size of furnace to the amount of energy available, any desired temperature may be attained up to that of the destruction of the container for the resistor. Where linings must be used in the crucibles, their melting or vaporizing fixes the maximum temperature at which the furnace may be successfully used.

IV. The crucibles are buried in the source of heat, and hence are heated more rapidly, effectively, and probably more uniformly than in some other furnaces; *e. g.*, in the arc furnace, where the source of heat is on one side only.

V. For heating a half dozen crucibles at once it has proved more economical of energy than the arc furnace.

Some of its disadvantages are:

I. The need of a variable voltage for the most satisfactory operation.

II. It is, so far as developed by the writer, an intermittent furnace, and hence wasteful of energy.

III. It contains a large mass of material other than the crucibles and charges, viz.: the resistor, which must be heated to the maximum temperature attained.

Laboratory of Applied Electrochemistry, University of Wisconsin.

Faraday Society.

The twenty-first ordinary meeting of the Faraday Society was held on June 12, 1906. Mr. W. Murray Morrison being in the chair.

ZINC DEPOSITION AND ROTATING CATHODES.

A paper on *The Electrolytic Deposition of Zinc, Using Rotating Electrodes,* by Dr. T. SLATER PRICE and Mr. G. H. B. JUDGE, was communicated by Dr. Mollwo Perkin.

An improved form of apparatus for the electrolytic deposition of metals using a rotating cathode, is described. The ordinary beaker is replaced by a tap funnel of about 100 c.c. capacity, so that the electrolyte can be run off at the end of the experiment, thus obviating the use of a siphon. Use is made of a bicycle hub for rotating the cathode.

In the deposition of zinc from a pure solution of the sulphate, no extraneous electrolyte being added with a current of 2 amps. (cylindrical) cathode of gauze, 22 mm. in diameter and 40 mm. long), and voltage 4.5-5.5. the results are uniformly low. The error increases with higher currents, and is due to the heating effect of the current. On keeping the electrolyte cool by means of an ice jacket good results are obtained, even in the presence of free sulpuhric acid, provided that the concentration of the latter does not exceed a certain amount (about one-sixth normal).

It is further shown that zinc can be quantitatively deposited from solutions of zinc sulphate, containing 0.2274 grm. zinc in the presence of 2–3 grms. sodium sulphate. The deposit is better than that obtained by the usual method, using sodium acetate and acetic acid; it is not necessary to cool the electrolyte.

An improvement of the method of Kolloch and Smith (*Journ. Amer. Chem. Soc.*, 1905, **27**, 1,255), using a rotating anode and mercury cathode is also described. It is found necessary not to have present more than two drops (40 drops = 3 c.c.) of free sulphuric acid in order to obtain quantitative results in the estimation of zinc.

A paper by Dr. F. MOLLWO PERKIN described *A Simple Form of Rotating Cathode for Electrochemical Analysis.*

The cathode consists of a spiral of platinum wire or, better, iridio-platinum wire. Nickel wire may be substituted for platinum, and the author recommends its employment in place of the more expensive metal. Attention is also drawn to the solubility of platinum anodes, with heavy currents 0.0016 grm. being dissolved in a cyanide solution in 35 minutes.

ELECTROLYSIS OF THIOCYANATE SOLUTIONS.

Mr. S. BINNING and Dr. F. MOLLWO PERKIN presented a paper on *The Electrolysis of Solutions of Thiocyanates in Pyridine and in Acetone.*

On oxidation of thiocyanates with chlorine, persulphates, etc., a yellow coloring matter—canarine—is obtained. By electrolysis of aqueous acidified solutions of thiocyanates an apparently similar product, which was originally described in 1884 by Lurdow, is obtained. The authors consider that this substance is not identical with the canarine obtained by chemical means, because it shows certain reactions not given by the oxidation product. They find that in alkaline solutions no coloring matter is produced, but that cyanides are apparently formed. A difficulty met with in the electrolysis was the formation of the coloring matter on the anode surface, which caused a great resistance to the passage of the current. The difficulty was got over by using a lead cathode on which bristles had been fixed. This was rapidly rotated within a cylindrical platinum anode, the bristles cleaning the anode surface as the cathode rotated. With a current of 5 amps. (10 amps. per square decimeter) the e. m. f. was 5 volts.

Anhydrous ammonium thiocyanate readily dissolves in dry acetone and pyridine, in either case there being no difficulty in obtaining a 20 per cent solution. These solutions readily conduct the electric current. In the case of the acetone solution with a current of 1.5 amps. (3 amps. per square decimeter) the e. m. f. required is 6.7 volts. With pyridine for the same current it is about 9 volts. In the case of the acetone solution a yellow amorphous powder separates out. With the pyridine solution the liquid becomes orange red, but no precipitate is produced. On pouring this orange solution into a large excess of water an orange precipitate falls out. These two substances are certainly not identical with the canarine obtained by oxidation; at present the authors are unable to say whether the product obtained from acetone is the same as that produced from pyridine. It is found that when a lead anode is employed in the pyridine solution it goes into solution; lead thiocyanate is produced and metallic lead is deposited at the cathode.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

ELECTRIC FURNACES.

Regulation of a Group of Electrodes in an Electric Furnace.—W. K. Gibboney, 821,936, May 29. (Assigned to the Pittsburg Reduction Co.). Application filed Nov. 19, 1904.

The object is to regulate independently and automatically a group of electrodes in an electric furnace, so as to maintain constant and uniform conditions. The inventor provides each electrode with a regulating electromagnetic device which is operated automatically by a current derived from the current passing through the electrode, and he opposes the action of this derived current by an independent electromagnetic force. By varying the strength of this opposing electromagnetic force by appropriate means, the current supplied to the electrode can be varied as desired. The electrical details of the arrangement are described and diagrammatically shown.

Combined Non-Regenerative Reverberatory Furnace and Electric Furnace.—E. A. Touceda, 823,560 and 823,561, June 19. Application filed Jan. 28, 1905.

In non-regenerative reverberatory furnaces as used, for instance, for preparing iron for malleable castings, a very large

percentage of the heat units produced escapes through the stack and is wasted. To utilize them the inventor provides a steam boiler between the hearth chamber and the stack. This boiler works in connection with a steam engine, driving a dynamo. The electric current thus generated is supplied to two electrodes in the hearth chamber.

Compound of Carbon and Silicon for Incandescent Lamp Filaments.—W. G. Clark, 821,017, May 22. Application filed Jan. 24, 1906.

A non-porous and non-crystalline compound of carbon and silicon, claimed to be suitable for incandescent lamp filaments and harder and more durable than carbon filaments, is produced by decomposing a carbonaceous gas in the presence of a volatile silicon compound; for instance, by passing an electric current through a carbon filament in the presence of a mixture of hydrocarbon gas and the vapor of silicon tetrachloride. The compound is different from carborundum; it is formed at a temperature lower than the fusing point of carborundum, and is a conductor of electricity when cold. Very little exact information is given. The inventor is uncertain whether it is a chemical compound or an intimate mechanical mixture.

Carbon Holder for Electric Furnaces.—G. O. Seward, 824,153, June 26. Application filed May 3, 1904. (Assigned to Willson Aluminum Co.)

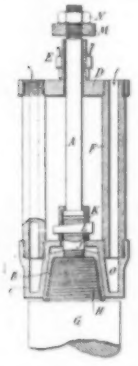


FIG. 1.—CARBON HOLDER.

Mechanical details of construction of the carbon holders fro mwhich the electrodes are suspended and through which the connection of the electrode with the line is made. The carbon holder comprises a suspending rod A (Fig 1) which is connected to the electrode G by a contact member B, and a connecting device for carrying the current to the electrode. The connecting device comprises a ring C, surrounding the contact member B, a guide D surrounding the suspending rod A, and having an upward projection to which is connected the line cable E, and hollow members F, connecting the ring C with the guide D. The electrode G is supported within the contact member B. The latter is in the form of a metallic bushing or cap or head formed with tapered screw-threads, corresponding with similar screw-threads H formed on the top of the electrode. B is connected with A by the rod J screwed into the top of B and fitting within a ring K, carried on the lower end of the suspending rod.

Titanium-Steel.—A. J. Rossi, 822,305, June 5. Application filed May 20, 1902.

The inventor whose pioneer work for titanium is well recognized, patents the following electric furnace process for making steel containing between 1 and 5 per cent of titanium and a desired amount of carbon. He feeds into the furnace an ascertained quantity of molten cast iron having an ascertained content of carbon, and then, without the aid of an air blast, he introduces into the molten cast iron a predetermined quantity of granulated oxides of titanium, calculated to be sufficient to decarburize the iron to the required extent. By regulating the current, he then increases the temperature to 3,200° or 3,500° F., for the reduction of the oxide of iron and also of the titanic acid by the carbon of the pig iron. This results in the decarburizing of the iron while the freed titanium is simultaneously alloyed with the iron. (The peculiar feature of the process is that the inventor introduces the titanium into the steel not in form of ferro-titanium; the employment of a ferro-alloy has the advantage that no particularly high temperature is required in the steel furnace itself, while Mr. Rossi must raise his whole steel bath to the reduction temperature of titanium oxide, though his process has other advantages.)

Electrolytic Processes.

Electrolytic Water Purifier.—A. E. Dieterich, 823,671, June 19. Application filed April 10, 1906.

A drum casing contains a double spiral screw of aluminium serving as electrodes. They form a spiral passage from one end of the casing to the other. While the water passes through it is subjected to electrolysis. The screw is rotated at times, in order to eject the precipitate from the apparatus without removing the electrodes.

Recovering Precious Metals from Water.—C. E. Holland, 818,174, April 17. Application filed June 5, 1905.

The object is to recover the precious metals from running streams in the vicinity of gold and silver mines. The inventor estimates that in the majority of cases stamping mills, combined with amalgamating and concentrating systems, lose from 20 to 50 per cent of their gold in this manner, this amount going to waste in the streams. The inventor conducts the stream of water through an electrolytic tank with aluminium or iron electrodes. Thereby the organic and inorganic matter in suspension or solution is coagulated or precipitated, the coagulations and precipitated matter containing practically all the gold and silver. This product is conducted from the tank to drying tables, tanks, pans, retorts or similar appliances, where it is subjected to a process of evaporation, decantation or filtration, the gold and silver remaining in powdered or granulated form in the residue. The precious metals are then recovered by treatment with a cyanide solution or in some other way.

Electrolytic Production of Oxygen and Hydrogen.—K. J. Vareille, 823,650, June 19. Application filed Nov. 15, 1905.

The object is to have the electrodes of opposite polarity near together, in order to decrease resistance and energy consumption, and to prevent at the same time the oxygen and hydrogen from mixing. The construction is shown in Fig. 2, where 13 are the electrodes connected to the rods 14, with the terminals 16 (positive) and 17 (negative) at the top. The electrodes 13 are of corrugated sheet iron. They are separated from each other by means of troughs 20 provided with insulators 18. Through the funnels 22 and pipes 23 the cell is filled with electrolyte. The oxygen gas is collected in a receiver in the center, the hydrogen gas in two receivers at the left and right.

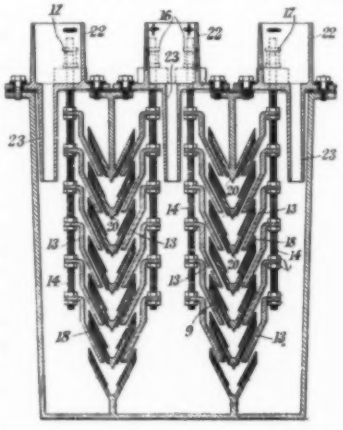


FIG. 2.—PRODUCTION OF OXYGEN AND HYDROGEN.

Batteries.

Alkaline Storage Battery.—T. A. Edison, 821,623, 821,624, 821,625, 821,626, 821,627, 821,628, May 29. Applications filed at various dates between Nov. 2, 1904, and May 26, 1905.

821,623 refers to a battery-filling apparatus so deviced that a positive notification is given when the electrolyte reaches the proper level. For this reason an electrode is provided at the proper height, which closes a circuit when the electrolyte rises to the predetermined level. 821,624 refers to a modification of his former construction of the gas separator, in which he used a perforated diaphragm or gauze in the top of the separator casing, through which the gases pass in a diffused and attenuated condition, in order to prevent the possibility of an ex-

plosion within the receptacle. Edison now provides the separator casing with a cover or auxiliary valve, which is normally closed to prevent the admission of any dust or dirt, but which will open by the accumulation of pressure beneath it to provide for the escape of the gases into the atmosphere. 821,625 refers to the removal of acid radicals, carbonates, organic matter and other soluble impurities from the active materials. These impurities are due to impurities in the chemicals or water used and are highly obnoxious. To remove them, Edison subjects the active masses to a treatment in a hot caustic solution with the concurrent generation of large quantities of hydrogen gas in situ within the active masses, the heating being effected, preferably electrically, by passing a discharging current through the active masses. The last three patents refer to three different methods of making cobalt films or flakes for admixture with the particle of active mass of nickel hydroxide. In 821,626 Edison deposits by electrolysis a film of zinc on a copper cathode, and then a thin film of cobalt on the zinc. By treatment with dilute acid the zinc is dissolved and the insoluble cobalt film thereby separated. The process of 821,627 consists in subliming cobalt chloride to deposit it in form of scale-like or crystalline flakes, then reducing the chloride flakes to the hydroxide state, and finally reducing the hydroxide to the metallic state. In 821,628, Edison fuses a sulphur compound (sesquisulphide) of cobalt and cools the fused mass, which results in the crystallization of the metallic sulphur compound in thin scales or films. By screening, non-scaly crystals are eliminated. Finally, the scales are roasted and oxidized and then reduced to the metallic state.

Storage Battery.—G. A. Ford, 824,348, June 26. Application filed July 20.

Details of construction, the character of which is best indicated by claim 9: "in a storage battery, the combination of a supporting pan or tray of non-conducting material, an electrode plate within said pan having a central tapering web, with vanes between it and the edges of said plate, said vanes lying at an angle to the plane of said plate, and an auxiliary electrode plate having a tapering web coextensive with said other tapering web and provided with fins between said vanes."

SYNOPSIS OF PERIODICAL LITERATURE.

A Summary of Articles Appearing in American and Foreign Periodicals.

ELECTROCHEMISTRY.

Electric Copper Smelting.—In *The Mexican Investor* of March 17, A. Bosch gives an interesting comparison of the relative cost of electric smelting and ordinary blast-furnace smelting of silicious gold-silver ores, with copper as a collector for the values. The comparison is made for a 400-ton plant on the basis of cost of coke of $12.00 per ton and $4.50 for the electric horse-power-year. Under these circumstances the author finds that the electric process allows a saving in fuel cost of about 43 per cent of the cost of the blast-furnace process. For a 400-ton plant, about 27,500-hp. water-power must be developed. The author recommends to develop about 10,000 hp. more selling electric power in the neighborhood. The total net profit of the combined power plant from the sale of electric energy at $80.00 per horse-power-year would then be about 7.9 per cent interest on the invested capital. While this might be considered too low, it should not be forgotten that the chief business is the smelting process, and that the distribution of electric power to mining regions by the smelting company would stimulate further mining, aiding indirectly to the prosperity of the smelter. As the final result of the comparison, the "total smelting cost" per ton of material treated is given as $2.48 with coke-fuel and $1.46 with electric current, representing a saving of $1.02. The pre-eminent advantage in electric copper smelting is the greater rapidity of fusing the charge, due to a higher temperature at the smelting zone. This results in a larger output and also permits to change the ordinary silicious slag into a higher silica-lime slag, without endangering the necessary fluidity of the slag. In a note attention is called to the availability of the great falls of Juanacatlan, near Guadalajara for such electric smelting developments. "The industrial interests of a country around a great waterfall are far more important than the profits brought in by tourists to simply see the waterfall. There is no comparison to be made between these interests." Mr. Bosch adds that "to see a mass of water falling is a very childish pleasure, and those people advocating the preservation of great waterfalls should compare the labor conditions in coal centers and those around hydraulic power centers."

Disinfection by Hypochlorites in England.—Concerning the new disinfecting plant of the Metropolitan Borough of Poplar, the following information is given in the London *Electrician* of June 1. The apparatus which deals with 185 gallons per day of 8 hours, "takes up a surprisingly small amount of space." The electrolyzers are arranged in four tiers or terraces. The electrolyte, which consists of 20 parts of a saturated solution of magnesium chloride with 100 parts of a saturated solution of sodium chloride, flows into the first set of cells at the top of the terrace at the rate of 3⅛ pints per minute, and here the solution attains a strength of about 1 gram of available chlorine per liter. It then flows over into the second cell, where the amount of available chlorine is about doubled, and so on to the third and fourth, when it leaves the apparatus, carrying about 4 grams of active chlorine per liter. Each cell contains zinc cathodes and platinum anodes (consisting of thin platinum wire wound over flat slate surfaces). Great difficulty was first experienced in getting a stable solution, it being found that within a few hours the oxidizing properties were very much reduced. This difficulty has now been gotten over by adding small quantities of magnesia to the electrolyte as it leaves the electrolyzing cells, thus neutralizing the free hypochlorous acid. By this treatment the solution when kept in closed carboys or bottles keeps its strength for weeks and even months. The four rows of cells contain forty electrodes and are connected in series, which are worked with a current of 15 amps. at 240 volts. A certain amount of the current energy is dissipated in heat, the solution entering the apparatus at 60° F. and leaving it at about 90° F. It is not possible to obtain solutions of much greater strength than 4 grams per liter, without using some external method for cooling. As, however, the solution is always diluted before being used for disinfecting purposes, there is no necessity to increase the amount of active chlorine in it. From time to time it is necessary to clean the electrodes which become coated with magnesium oxychloride. The formation of this oxychloride, although to a certain extent a disadvantage, is also of use because it helps to prevent the cathodic reduction of the hypochlorite. When preparing sodium hypochlorite it is found advantageous to add small quantities of a magnesium or calcium salt in order to minimize reduction. The Poplar Borough Council distribute the disinfectant fluid in bottles, and use it for watering the streets. "It most certainly has very powerful deodorizing properties, the extremely offensive odor from a bucket of very rotten fish was almost immediately suppressed

by pouring on about 1 pint of the fluid. Whereas, 1 pint of carbolic fluid costs 17 cents, the hypochlorite fluid (which concentration?) with electric current at 3 cents per kw-hour, only costs 1 cent." A fuller description with illustrations may be found in London *Electrical Review* of June 8.

Electric Annealing Furnace.—In treating metals, especially in hardening tool steels, it is most important for various purposes to heat them uniformly for a certain time at a distinct temperature. Any lack in uniformity of heating metallic pieces (especially with pieces of irregular cross-sections) results in flaws. In *Elekt. Bahnen* of May 14, a note is published on an electric furnace of Koerting Bros., of Berlin, in which the metal pieces to be heated are placed in a fused salt bath, the alternating current for heating being introduced through two cast iron electrodes from the secondary of a transformer; by changing the number of secondary windings the temperature may be easily regulated. For a furnace of "medium size" it is stated that per c c of bath about 0.25 watts are required for a temperature of 750° C., 0.6 watts at 850°, 1.4 watts at 1,000°, and 3 watts at 1,300°. No further technical details are given.

Formation of Ozone.—To produce ozone by electric discharges of air it is necessary to employ the silent discharge, the formation of arcs being fatal. It has been suggested that the formation of ozone is ultimately due to the ultra-violet light of the brush discharge. In connection with this point some notes by G. A. Vosmaer (whose process of making ozone was described in our Vol. II., p. 511) in the London *Electrician* of June 8, are of interest. He found that ozonized air is a worse conductor of electricity than ordinary air. Since it seemed probable that a certain amount of ionization is produced by the brush discharge, the ozone generated was tested for its property of discharging a charged electroscope, but with entirely negative results. Against the hypothesis of formation of ozone being due not to the electrification, but to the ultra-violet light he mentions the fact that if one discharger is working to its full extent, its luminosity (and output in ozone) is greatly diminished by the proximity of another, so much so that if the second discharger is placed at a distance of less than an inch, both are nearly extinguished, and if there is a third the middle one entirely stops working. This is a very remarkable fact, and is one of a great many unexpected phenomena which take place in connection with the production of ozone and upon which the author is still conducting some researches. The author experimented with a 20-kw plant of his own design, in which the dischargers consisted of one sharp edged and one flat pole connected to a 100-period 10,000-volt transformer, special arrangements being adopted to prevent sparking across.

Flour Belaching with the Aid of Electric Discharges.—In the London *Electrician* of June 8 the process of the Alsop Flour Process Company is described. A current of air is passed through a chamber containing a long, high-voltage continuous-current arc, and this air is then used for treating flour in an agitator. The result of this treatment is that the flour emerges from the agitator with a considerably whiter color. Two patterns of apparatus are employed. In the form shown in Fig. 1 a double-acting pump draws the air from the inlets H H through the chambers A A, which contain the arc, whence it passes through the pipes C C to the cylinder B of the pump. The pump-piston rod G is driven by a pulley on the shaft F, and is connected through links to the rods E E, to which the upper electrodes of the arc are attached. On removing the covers, attached to the chamber A by means of the insulated handles, the arc is visible, and the inside of the chamber can be got at for cleaning and for replacing the electrodes. Current is led in by the wires D D D. The electrodes between which the arc is struck are usually of mild steel or iron, and are insulated from the walls of the chamber. They are provided with taper ends, which fit taper sockets, and, whilst being securely held, are easy of replacement. The suction-stroke of the pump starts when the electrodes are together, and thus the air flows through the chamber as the arc is being lengthened by the raising of the upper electrode, until the arc is extinguished. During the pressure part of the stroke, the upper electrode descends again. As the pump is double acting there is a continuous stream of air, first through the arc chamber on one side and then through a similar chamber on the other side. A simple clutch arrangement similar to an arc lamp clutch allows for the burning away of the electrodes.

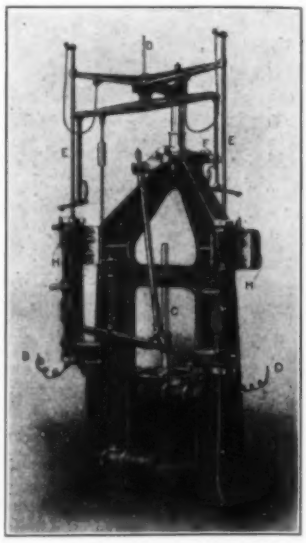


FIG. 1.—APPARATUS FOR PASSING DISCHARGES THROUGH AIR FOR BLEACHING FLOUR.

The stroke imparted to the rocking lever is slightly longer than the maximum distance between the electrodes, and when the latter come together the spring-controlled clutch releases the rod E for the remainder of the stroke. A generator voltage of 400 is employed, but, to increase the length of the arc, an inductance of considerable size is included in the circuit. The length of arc employed is from 2 inches to 5 inches, according to the size of the pump. The apparatus of the type shown by Fig. 1 is made in three sizes: 4-inch piston diameter by 4-inch stroke, 7 inches x 7 inches and 10 inches x 10 inches, and the speed is 50 r. p. m. With the largest sized pump, thirty sacks of flour can be treated per hour. There is in all cases a small resistance in series with the arc, which provides for an adjustment of current in addition to that obtained by altering the inductance in the circuit. The current employed ranges from 1½ to 12 amps. in the largest size according to the output of flour, or the bleach required. The second pattern described is designed for smaller outputs.

An American patent of the same company was analyzed on page 240 of our June issue. As to the rationale of this process it is to be remarked that in this case arc discharges are employed so that probably compounds of nitrogen and oxygen are formed in the air and the bleaching effect is due to these compounds. Essentially different from this method are those processes (proposed by others) in which ozone is used as bleaching agent and is produced by the silent electric discharge through air. S. Letham (our June issue, p. 240) claims that the best results are obtained by treating the air successively first by the silent electric discharge and then by an arc discharge. Methods of this kind for whitening flour are reported to be in commercial use to some extent in the Middle West and South, but no exact information is available.

Generation of Hydrogen from Calcium Hydride.—For preparing hydrogen gas (for filling balloons and other purposes) quite a number of different methods are in use or have been proposed. Among the latest ones is the use of electrolytic iron, suggested by Burgess, as noticed in our June issue, page 224. In the meanwhile an observation of Moissan has led in France to the industrial preparation of calcium hydride. It was shown by Moissan that metallic calcium absorbs hydrogen when heated, forming the colorless hydride CH_2. This is now made industrially and sold under the name of hydrolyte. Some notes concerning it are given in a paper by Jaubert in *Comptes Rendus*, Vol. 142, p. 788; abstracted in *Am. Jour. of Science*, June. Calcium hydride is well adapted for generating

hydrogen, since it reacts with water according to the equation: $CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2$. The reaction is thus quite analogous to the generation of acetylene from calcium carbide. One kilogram of the substance thus liberates a cubic meter of pure hydrogen. Metallic calcium is manufactured by the electrolysis of the fused chloride. The electrical energy required for producing 100 kilograms of the metal in 24 hours is about 20 volts and 7,500 amps., or 150 kilowatts. The hydride is prepared by heating the metal to a high temperature in horizontal retorts in which hydrogen circulates. The gas is slowly absorbed, and after several hours all the calcium is transformed into the hydride. The commercial product occurs in white or gray, irregular porous pieces, having considerable hardness. It is insoluble in the common organic solvents, but is instantly decomposed by cold water, similarly to calcium carbide. The product is about 90 per cent pure, the impurities being chiefly oxide and nitride.

IRON AND STEEL.

IRON AND STEEL INSTITUTE.

The annual spring meeting was held in London, May 10 to 12, President R. M. Hadfield in the chair. The Bessemer Gold Medal for 1906 was awarded to Floris Osmond, of Paris, and the Carnegie Gold Medal to L. Guillet, also of Paris, thus suitably recognizing the splendid work of the new French school. A special silver medal was awarded to W. Rosenhain, of Birmingham, and Carnegie scholarship grants to H. C. Boynton and E. Hess, in the United States. The following abstracts of the papers presented at this meeting we have prepared from the special number of the *Ironmonger* of May 12:

Compression of Steel Ingots in the Mould.—A. J. Capron, of Sheffield, described a process of fluid compression wherein the moulds are divided into two parts vertically, with a loose packing in the joint, and are compressed by horizontally applied pressure. Several moulds may be placed tandem, that is, in series, and the same pressure then acts on all. In this case all the moulds must be filled at the same time, either from a trough or a bottom gate. Within a few minutes after casting the ingots shrink from the mould, the loose packing pieces are removed and the pressure applied until the ingots are solid. Groups of small ingots of only 80 pounds weight each are treated with great success. The power required is comparatively small, 30 hp. being sufficient for an 8,000-ton press dealing with a cast of 60 tons of steel. In the discussion, Mr. D. V. Pirie claimed that the Hermé process of fluid compression is the best so far devised; with it, ingots of 25 to 30 tons can be cast absolutely solid from top to bottom without a blow-hole the size of a pin-head.

Cooling of Cast Iron.—Prof. Thomas Turner, of Birmingham, discussed the volume and temperature changes taking place during the solidification and cooling of cast iron. In his experiments a bar was cast in a sand mould in the shape of a T, which kept one end fixed while the other was free to contract or expand. A thermo-couple indicated the temperature. A wire nail is inserted into the free end, so that as the metal flows around it it becomes embedded, and its free end is in contact with an extensometer multiplying the movement forty times. Copper, aluminium, antimony lead, tin and zinc give a uniform contraction curve, without any arrests or kinks. White, washed American pig iron, containing only iron and carbon, gave a contraction and cooling curve having one marked arrest, at 665°, evidently coincident with the formation of pearlite. Gray hematite iron containing 3.47 silicon and 0.55 manganese showed a slight expansion at 1,135° just after setting, and an equally strong expansion at 695°. Phosphoric grey iron from Islip, Northampton, carrying 3.98 silicon, 0.50 manganese and 1.25 phosphorus, showed a very strong expansion at 1,060° just after setting, another small expansion at 900°, not observed in the other samples, and a very strong expansion at 730°, evidently corresponding to the arrests at 695° and 665° in the purer samples. In conclusion, the author pointed out that the tests can be readily made, and would give a foundryman very practical and valuable information respecting the casting qualities of his irons or mixtures of irons.

Chilling of Cast Iron.—E. Adamson reported tests on the influence of silicon, phosphorus, etc., on chill casting. The conclusions drawn are that the depth of chill is primarily dependent upon the percentage of combined carbon and the temperature of casting. Total carbon and combined carbon are the definite factors, graphitic carbon rather a negative factor. Silicon reduces the amount of chill, but the amount of this reduction to be expected cannot be deduced from the amount of silicon alone, as found by analysis. Phosphorus reduces the true chill, but it rather increases the interlacing effect between the white and grey portions, and therefore is not altogether harmful. Manganese increases the depth of chill, and below 1.17 per cent does not interfere materially with the mechanical properties. Aluminium decreases the depth of chill.

Manganese-Iron Alloys.—Prof. Arnold and F. K. Knowles contributed a preliminary note on alloys of these two metals containing only 0.1 to 0.2 per cent of carbon and silicon; 13 to 20 per cent manganese alloys worked like tool-steel; 20 to 35 per cent behaved like hard tungsten steels. The general opinion expressed in the discussion was that the paper was incomplete and prematurely written.

Thin Steel Sheets.—Mr. E. F. Law discussed "Brittleness and Blisters in Thin Steel Sheets." Blistered sheets are usually, but not invariably, brittle; on the other hand, many brittle sheets show no signs of blisters. Heat treatment does not remove the brittleness, which is, moreover, not due to improper heat treatment in the first case. Microscopical examination showed that brittle and blistered sheets were invariably impure from segregation of sulphur phosphorus and apparently also iron oxide. Manganese sulphide and manganese carbide, rich in phosphorus, tend to roll out into thin lines and sheets, so that in thin, black plates their influence in making lines of weakness is far from negligible. The final conclusions were that oxidized steel is more liable to give blistered sheets, and that large ingots which segregate in cooling tend to give brittle sheets, because of the segregation of the impurities.

Copper in Steel.—F. H. Wigham reported results of numerous tests of the properties of steel containing copper. Difficulty was found in getting the copper alloyed; one method used was to put the copper into the steel as it ran into the moulds, and to add likewise up to 1 per cent of aluminium to facilitate the alloying. This method is open to several grave objections, such as the lack of time for alloying and the simultaneous effect of the aluminium. The results of the tests were that 0.6 per cent of copper is the limit allowable in steels containing 0.5 per cent or more of carbon, while 0.25 per cent of copper is no disadvantage at all in the manufacture of wire. Low carbon steel with up to 0.5 per cent of copper welded without difficulty and drew into wire perfectly.

Rolled Steel Wheels and Tires.—P. Eyerman, of Benoit, Wis., described the manufacture of solid rolled car wheels and tires, such as has been long known, and was described in America by Mr. Vauclain in the *Journal* of the Franklin Institute for February, 1905.

Chain Making Machinery.—E. Lelong described a machine which takes in the heated bar if iron and makes the links either interlocked or separate, making 100 to 120 links of ⅝-inch chain per hour. It is claimed that the machine-made chain is 20 to 25 per cent stronger than chain made by hand from the same bar material.

Fracture of Steel.—C. O. Bannister, of London, discussed at length "The Relation Between Fracture and Micro-Structure of Steel Test Pieces." He distinguishes five types of fractures of test pieces: cup, laminated, irregular, crystalline and slip or oblique fractures, mechanical, chemical and microscopic data, all very complete, accompanied by photographs and microphotographs are then given for six specimens of material

breaking with each kind of fracture. Cup fractures occur only in breaking circular bars of the best steels. Laminated fractures are associated with steels showing "ghost lines," which may often give excellent mechanical tests and satisfactory chemical analyses, but yet are not good steels because of their laminated nature, as shown up in the fracture. Irregular fractures are generally associated with inferior steels, and are always associated with slag lines or well-developed "ghost lines." These steels consist of irregular patches of pearlite, more or less surrounded by ferrite, along which the specimen has a tendency to break. The extended investigation of steels with crystalline or slip fractures is not yet completed. The frequent occurrence of manganese sulphide and silicate in commercial steels fully justifies their being classed as important constituents, and kept in view in examining the steel.

Copper.

Melting Point.—M. P. Dajean, in *Revue de Metallurgie* for May, redetermines the melting point of copper by the very simple method of using a Le Chatelier couple, and finding by comparison that "best selected" copper melts at 20° higher than pure gold. "Admitting" (as the French like to say) that gold melts at 1,065°, then copper melts at 1,085°, since 1065 + 20 = 1085, "as nobody can deny." When the copper contains Cu^2O, its melting point falls to a eutectic carrying about 5.0 per cent Cu^2O, and having a melting point 25° below that of pure copper. The alloys of copper with aluminium show a regular reduction of the melting point at the rate of approximately 5° for each per cent of aluminium added. Dajean recommends using copper for standardizing thermo-couples, allowing it to oxidize freely, so as to get the eutectic melting point. It appears to us preferable to keep the copper deoxidized by means of charcoal, and thus avoid any uncertainty as to whether the eutectic has been reached or not.

Copper and Sulphur.—E. Heyn and O. Bauer describes in *Metallurgie* for Feb. 8, an extremely interesting and important research on the fusing points and eutectics of copper and cuprous sulphide. With pure copper melting at 1,085°, and cuprous sulphide at 1,127°, the diagram was completed for all admixtures of the two, 3.8 per cent of cuprous sulphide, representing 0.76 per cent of dissolved sulphur, forms a eutectic melting at 1,067°. This eutectic showed itself on the cooling curve from 1 up to 95 per cent Cu^2S. Above 3.8 per cent an upper melting point above the eutectic rises rapidly, up to 9 per cent Cu^2S, melting at 1,102°. From this point up to 85 per cent Cu^2S the melt consists of two inimiscible layers, one the eutectic of Cu^2S saturated with Cu., and melting at 1,102°, the other, the eutectic of Cu. saturated with Cu^2S, melting at 1,067°. Above 85 per cent of Cu^2S a new melting point appears, running up steeply to that of pure Cu^2S at 1,127°. The microscope showed clearly characteristic appearances for these eutectics and their component parts; hydrofluoric acid was found the best etching solution, since it turns cuprous oxide black, but leaves cuprous sulphide blue.

Special Brasses.—The indefatigable Guillet adorns *Revue de Metallurgie* for May with a 46-page treatise on special kinds of brass. He has studied carefully the copper-zinc, or ordinary brasses, and he then determines by careful comparative micrographic study how many per cent of zinc are replaced by each per cent of an added foreign element, such as aluminium, lead, phosphorus, etc. This ratio he calls the equivalence of the element added. The studies were made on brasses containing 49 to 67 per cent of copper. The results showed that 1 per cent of aluminium replaces 6 per cent of zinc; that the equivalence of aluminium may be called 6, and that a large percentage of aluminium about 10, is necessary to give any special characteristics to the alloy not possessed by ordinary brasses. Manganese has an equivalent coefficient of 0.5. Iron, up to 1.66 per cent, has an equivalent coefficient of 0.9. Tin has the coefficient of 2. Lead may go into solution up to 0.9 per cent, and then has a coefficient of about 1. Silicon dissolves to the extent of 1.4 per cent in brass of 63 per cent copper, and 2 per cent in brass with 90 per cent copper; its coefficient within these limits is 10. Magnesium dissolves only to the extent of 0.2 to 0.3 per cent, and has a coefficient of 2. The presence of more magnesium is extremely injurious to the mechanical properties of the brass. Antimony acts quite similarly to magnesium.

Nickel.

Nickel-Silicon Alloys.—Guertler and Tamman (*Z. für anorg. Chemie*, 1906, **49**, 93; *J. Soc. Chemical Industry*, May 15) have studied these alloys, and by the melting points have proved the existence of Ni^2Si, Ni^3Si, Ni^5Si^2, NiSi and Ni^2Si^3. The softest alloys are stated to be those with 40 to 50 per cent of silicon. Those with up to 10 per cent of nickel can be worked easily when cold, but not at a red heat; they are softer when quenched than if cooled slowly from a high temperature.

Nickel-Antimony Alloys.—K. Lossew (*Z. für anorg. Chemie*, 1906, **49**, 58; *J. Soc. Chemical Industry*, May 15) found from the melting points only two compounds of these two metals, NiSb and Ni^5Sb^2. Starting from antimony, melting at 630°, the first eutectic point is at 611°, with between 2 and 3 per cent of nickel; it then rises to the first maximum, at 1,158°, corresponding to NiSb, with 32.83 per cent of nickel. From 32.83 to 54.97 per cent nickel mixed crystals of NiSb and Ni^5Sb^2 are produced; at 54.97 is a maximum of 1.170°. From Ni^5Sb^2 to 66 per cent nickel the melting point falls, the second eutectic, at 66 per cent, melting at 1,100°. From here on the melting point rises to that of pure nickel. In these alloys the compound Ni^3Sb forms at 677° C. if it is allowed to cool slowly in air; if quenched, this does not occur.

Slags.

Reaction Velocity and Viscosity.—C. Doelter, in the *Zeitschrift für Elektrochemie* of June 15 (this year), answers, as if by mental telegraphy, the query of Prof. Howe, contained in our correspondence column, page 258. Doelter divides silicate slags into two classes: such as possess when melted small viscosity and have a sharply defined melting point, and such as have greater viscosity and show no sharply defined melting point. The first class are simply constituted silicates, such as $CaSiO^3$, Mg^2SiO^4; the second are complex, such as $NaAlSiO^4$, $Na^2AlSi^2O^6$, $K^2Al^2Si^4O^{12}$. The latter can be considered as split up into their component simple silicates when melted, or into aluminates and silicates. These two classes are distinct, but there are transition silicates between them. The second class show while cooling an upper and a lower melting point, or point of arrest on the cooling curve, also a long period of solidification, and very low velocity of melting or crystallizing; the amount of undercooling observed is much larger, and they are much more inclined to form glassy slag than the first. The velocity of reactions in these slags is very small, because of their viscosity. In the first class, the speed of melting and crystallizing are very much greater, and chemical equilibrium intends to establish itself much quicker.

Of great importance is the difference between the two classes in respect to dissociation. The less viscous, simple silicates may in fact be dissociated, being partly resolved into their constituent oxides, aside from the question of content of free ions; as a consequence of decreased viscosity, the electrical conductivity of these slags increases rapidly as their temperature is raised. In every case, in these slags, ionization equilibrium is reached rapidly, and reaction velocity has a much higher value than in slags of the second class, and equilibrium is more rapidly reached.

In slags of the second class, thermolytic dissociation undoubtedly takes place; they are bodies representing a binary system. When melted they fall into their component silicates, and by long maintenance in the viscous condition other complexes than the original ones can be formed. Measurements of crystallization velocity and solution velocity in these complex silicates show only one-two hundredth the velocity found in the simple, less viscous slags.

There is, therefore, no doubt that such silicates of the second class are strongly resolved when melted, and that while cooling the former equilibrium is only very slowly restored, thus frequently causing the formation of a glass. Many such silicates, as Albite and Orthoclase, will on this account never be obtained crystallized from the melted state, unless additions of other bodies be made to accelerate the reaction velocity; small amounts of tungstic acid, vanadic acid or molybdic acid are in this respect active accelerators, and thus induce crystallization.

It has long been known to mineralogists that the simple silicates separate out first, and the complex silicates later, and that the quantitative relations relative to the eutectic mixture are not here the determining factors—as they are in alloys. The reasons for this are given by the low reaction velocity in complex melts.

The relations of silicates are therefore governed by the general reaction velocity, melting velocity, crystallization velocity, solution velocity, the velocity with which equilibrium is reached in the melted slag, and the particular reaction velocity of two reacting substances. These velocities are all, in their turn, dependent upon the *viscosity* of the slag, the reaction velocities being considerably greater with the thinner and least viscous varieties of slag.

RECENT METALLURGICAL PATENTS.

LEAD.

Smelting Lead-Sulphide Ores.—Mr. A. G. Betts, the indefatigable worker in lead metallurgy, has recently patented (821,330, May 22) a process of smelting lead ore which does not require the admixture of silicious ores and in which the losses of lead are reduced. The smelting charge consists of 65 parts lead sulphide, 20 siderite or limonite, or the equivalent amount of other iron oxides, 20 sodium carbonate, which may be in part replaced by the equivalent amount of caustic soda, and 12 to 15 parts fine coal or coke. In general the mixture will contain some silica, blende, pyrite, limestone or other gangue of the lead-sulphide ore. The principal reactions which take place when the mixture is heated are:

$$Na_2CO_3 + 3C + PbS = Pb + Na_2S + 3CO.$$
$$Fe_2O_3 + 3C + 2PbS = 2Pb + 2FeS + 3CO.$$

The mixture is preferably smelted in an ordinary reverberatory smelting furnace. The fusion takes place at a moderate temperature, yielding nearly all the lead of the ore as metal and an easily-fusible iron-sodium matte. Loss by volatilization of lead scarcely takes place at all when the charge is covered with a little coal, or the flame in the furnace is reducing. The mixture can be smelted in a blast furnace, which should be run so that there is an excess of carbon monoxide in the escaping gases. Success is attained by proportioning the furnace charge so that the matte produced contains considerable proportions of both iron sulphate and sodium sulphide, for the reason that the mixed sulphides melt at a comparatively low temperature, and the mixture does not hold in igneous solution appreciable quantities of metallic iron or lead, which is the case with iron sulphide alone. Sodium sulphide alone is difficulty fusible. The matte, leaving out of consideration silica, zinc, etc., best approximates in composition the formula Na_2S . FeS. As iron is a cheaper agent than soda, it is usually more economical to use more iron and less sodium than this formula requires. Iron ores containing manganese are equally as good as pure iron ores, since manganese acts analogously to iron. When sodium sulphate or sodium sulphide are available at a low price, the inventor may replace sodium carbonate as desulphurizer with iron oxide, and add enough sodium sulphate or sulphide to reduce the percentage of iron sulphide in the matte to a desirable figure. When sodium sulphate is used the following reaction occurs:

$$Na_2SO_4 + 4C = Na_2S + 4CO.$$

Pyrite mixed with the galena can be figured as yielding sulphur and ferrous sulphide, which latter forms part of the matte. Lead oxide, if present in raw or roasted ore, is directly reduced by carbon and takes no part in the formation of matte. Lead sulphate, if present, should be allowed for by allowing enough carbon to reduce it to lead sulphide, and then the lead sulphide produced should be figured as so much galena.

FURNACE CONSTRUCTION.

Tilting Furnace.—J. C. Cromwell (823,669, June 19, assigned to Garrett-Cromwell Engineering Co.) patents the tilting furnace shown in Fig. 1. It is of the usual construction of the open-hearth type, with gas and air ports BB leading from the regenerators, and is mounted upon a framework of girders C. The girder frame has at each end supporting brackets C^1, in which are journaled rollers C^2, adapted to ride upon the curved trackway D. The curvature of this trackway is that of a circle, having its center about the gas and air ports BB. The segmental rack D^1 serves for the tilting operation, an electric motor being used with suitable gearing. In the illustration the driving connection is shown as that of a worm-shaft E^1 and wheel E^2, transmitting power from the motor E to gears E^3E^4, which in turn transmit the power to cog E^4, meshing with the segmental rack D^1. This reduction device is stated to be very effective, the furnace being under absolutely perfect and positive control in all positions. This furnace may obviously be rotated about a given axle, which will be the

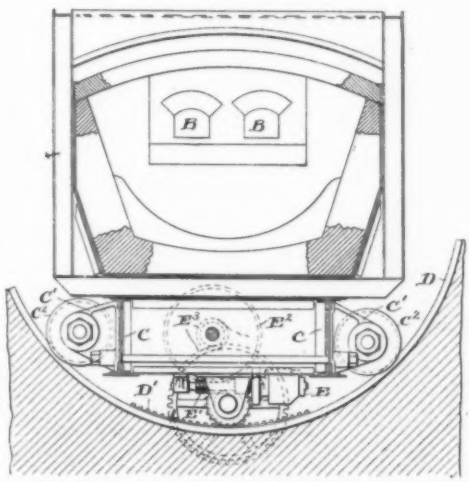


FIG. 1.—TILTING FURNACE.

line passing through the centers of curvature of the two supporting rails, and it is so designed that the shifting of the bath upon tilting will not disturb the state of stable equilibrium, the center of gravity being close to the axis of rotation. During rotation the fuel ports are not exposed to cold air, and combustion may be continued at all positions of the furnace. No matter how the furnace may expand under the influence of heat, the supporting frame upon which it is mounted always receives the thrusts along exactly the same lines, so that the original design will be effective and not disclose weakness under the changed conditions.

ALLOYS.

Alloy for Electric Resistance.—W. B. Driver (824,103, June 26) patents an alloy which is intended as a substitute for German silver for use as electric resistance. The disadvantage of German silver is that after repeated heatings and coolings in service it crystallizes and breaks. This is due to the presence

of zinc. Driver, therefore, uses no zinc. His alloy consists of 75 parts copper, 20 nickel and 5 manganese. It is said to have "a high and practically constant resistance," and to be permanent and stable in its physical and electrical properties.

Nickel Alloy as Substitute for Platinum.—C. W. Birmingham (824,618, June 26) patents the following alloy, which is said to be fusible "only at a very high temperature," and "may be used as a substitute for platinum, especially as employed in connection with electrical appliances." It consists of 16½ ounces Troy silver, 4½ pounds nickel, ½ ounce bismuth, and 53 pennyweights gold. The alloy is said to be "highly ductive and far more durable than platinum."

Copper Alloy.—G. Chandoir, Jr. (820,954, May 22), patents an alloy which has higher tensile strength and greater ductibility than copper, bronze or brass at high temperatures. He adds from ¾ to 3½ per cent of cadmium to the copper or bronze or brass. "By this addition the tensile strength of copper at the temperature of 500° C. is increased to 30.3 kg. per sq. mm. The increase of the ductibility is especially conspicuous in the alloys richer in cadmium. An alloy containing 92 per cent of copper, 4½ of tin, and 3½ of cadmium has shown especially good results.

Contact Process for Sulphuric Acid.

Rejuvenation of the Catalyser.—In an article in our Vol. II., p. 347, in which a concise summary was given of the principal engineering and industrial points which brought about the success of the contact process for the manufacture of sulphuric acid, attention was called to the absolute necessity of keeping the contact substance of finely-divided platinum free from impurities, especially arsenic. This means that an actual chemical elimination of everything, except sulphur dioxide, oxygen and nitrogen, is necessary before the gas is admitted to the contact compartment. How this problem has been solved in commercial practice was described in the article referred to. A recent patent of I. Kitsee (821,042, May 22) refers to the same point, but he does not try further improvements of the purification of the gases, but rather purification of the finely-divided platinum, which forms the satalyser, when "poisened" by arsenic and other impurities.

For this purpose he makes the finely-divided platinum the anode in an electrolytic cell with sulphuric acid as electrolyte. The principle of this method is that platinum is not dissolved, while arsenic, mercury, phosphorus, antimony and metals of the same class, known as "contact poisons," are readily dissolved and oxidized. To regenerate a contact substance which has lost its catalytic action on account of impurities, "it is only necessary to send a current density through the apparatus equal to 1 amp. for each ounce of contact mass, and the time to purify the same entirely varies from 1 to 3 hours." * * * "It is obvious that this contact mass can be made the electrode of an electrolytic apparatus during the time of the production of the sulphuric acid, and it is further obvious that in such cases the destructive influence of the contact poison is entirely obviated."

American Electrochemical Society.

At the June meeting of the board of directors the following gentlemen were elected members of the American Electrochemical Society: A. R. Johnson, Madison, Wis.; W. J. Rodgers, Philadelphia, Pa.; F. A. Stamps, Niagara Falls, N. Y., and H. T. Matthew, New York City. At the next meeting the names of the following two gentlemen will come up for election: R. A. Hadfield, Sheffield, England; R. C. Stofer, Norwich, N. Y.

The two vacancies in the board of directors, due to the election of Vice-President C. Hering to the presidency, and the resignation of Manager C. J. Reed, were filled by the board electing Mr. Alfred H. Cowles, of Cleveland, a vice-president, and Dr. Henry Noel Potter, of New York City, a manager.

The constitution of the board is now as follows: President, Carl Hering (till 1907); junior past presidents, H. S. Carhart (till 1907), W. D. Bancroft (till 1908); vice-presidents, E. F. Roeber, L. Kahlenberg, A. H. Cowles (till 1907), and S. P. Sadtler, J. W. Richards, Samuel Reber (till 1908); managers, W. H. Walker, C. E. Acker, E. Weston (till 1907), C. A. Doremus, C. P. Townsend, W. R. Whitney (till 1908), E. G. Acheson, C. F. Burgess, H. N. Potter (till 1909); secretary, S. S. Sadtler (till 1907); treasurer, P. G. Salom (till 1907).

The executive committee consists of Mr. Carl Hering, chairman; Mr. S. S. Sadtler, secretary, and Messrs. W. D. Bancroft, H. N. Potter, J. W. Richards, S. P. Sadtler and P. G. Salom.

The tenth general meeting of the Society will be held in New York City during October, 1906.

BOOK REVIEW.

Industrial Furnace and Methods of Control. By Emilio Damour. Translated from the French, with additions, by A. L. J. Queneau, B. S. (Paris), E. M., A. M. (Columbia), Consulting Engineer with the New Jersey Zinc Co. With preface by Henry M. Howe, LL. D. New York: *Engineering and Mining Journal*. 317 pages, 88 illustrations, 24 tables. Price, $4.00.

The ground covered by Prof. Damour's book is the discussion of the calorific powers of fuels, temperatures of combustion, heat balance sheets of various kinds of furnaces, chimneys, theory of generators, losses of heat by radiation and conduction. The translator has added excellent chapters on pyrometers, gas analysis, burning of powdered fuel, conversion tables, and a bibliography; and Dr. M. N. Bolles has contributed chapters on calorimetry and the analysis of fuels.

The work abounds in meritorious features, the discussions being often most illuminating. It also abounds in shortcomings, part apparently existing in the original and part to be laid to the translator. The commendable features are particularly the complete tabulation of the data throughout the book, the liberal use of curves, so as to exhibit the results of calculation graphically, the clear and numerous illustrations, the very readable and easily-understood style of writing, the fine typography, good paper and attractive binding.

The shortcomings are in some cases such as to need more extended allusion. One great drawback is that all heat calculations throughout the work are made per gram of material burned; grams are well enough for laboratory use, but it seems ridiculous, and has practical disadvantages also, to cast up a balance sheet of a 50-ton open-hearth furnace, for instance, per gram of fuel burned or of steel melted. All gas calculations are based upon first transposing the actual volumes of gases concerned (measured in liters instead of cubic meters), into molecular volumes, by dividing the real volumes by 22.32. This is an unfortunate policy, for no one except an expert chemist ever has a concrete idea of what molecular volumes represent, whereas, everybody knows what actual volumes are. Thus, to gain a theoretical advantage, the authors have sacrificed the only method of presentation which can be helpful and comprehensible to practical men.

Both Prof. Damour's and the translator's fundamental chemical definitions are sometimes faulty and misleading, atoms and molecules being confounded (as on page 8 and in Table I). Sensible heat and latent heat are used almost interchangeably throughout, as if they were synonyms. In discussing combustion, it is stated that no external work is done when it takes place under constant pressure, and this mistake is continued through the discussion.

Prof. Howe states that the translator's mastery of "our puzzling English rouses our applause," but we cannot fully share the professor's enthusiasm. One illustration may illustrate the point: "Axiom—The total quantity of air necessary for the fuel combustion, escaping through the stack as water vapor, carbon dioxide and nitrogen, is always the same for a given weight of the burned fuel."

In spite of these defects, there is so much valuable material in the book that it should be a desirable addition to every metallurgist's library.

THE ELECTRICAL NATURE OF MATTER AND RADIO-ACTIVITY. By Harry C. Jones. New York: D. Van Nostrand Co. 212 pages. Price, $2.00 net.

This is a collection of a series of articles published in the *Electrical Review*, carefully revised and brought up to date. The aim has been to present the important facts and conclusions in this field, as far as possible in non-mathematical language and in semi-popular style, but with strict scientific accuracy. The bulk of the work is an exceedingly clear and readable presentation of the whole field of radio-activity, numerous references being given to the original articles, so that any particular branch of the subject may be followed in detail outside the limits of this treatise. Prof. Jones has accomplished a very useful and very important work, in thus making accessible to the general reader the most recent advances in electrical and chemical science.

NOTES ON ELECTROCHEMISTRY. By F. G. Wiechmann, Ph. D. New York: McGraw Publishing Co. 145 pages. Price, $2.00

The six chapters of this elementary text-book deal with general principles (general principles of science, matter and energy, forms of energy, measurement of physical phenomena); electrical energy (theories of electricity, radio-activity, intensity factor and capacity factor of electrical energy, properties of electricity, Ohm's law); electrochemistry (evolution of electrochemistry, electrolysis, electromotive force, dissociation voltage); electrolytic dissociation (ion theory, conductivity, migration of ions); electro-analysis (electro-analysis, reversible reactions and cells, sources of current, current measurement, current regulation, electrodes, current density, records, resumé); electrotechnology (a very concise summary of the industrial applications of electrochemistry).

Differing from larger standard books on theory and applications of electrochemistry, "the present notes aim merely to offer a general survey of the subject, to serve as an introduction to its study and to aid in the securing of a proper understanding and appreciation of the work along individual lines." The strongest point of the book is the thorough way in which fundamental conceptions and principles are worked out. Without going deeply into details of electrochemical theories, the author succeeds in giving a good survey of the most important principles, the latest advances in physical science being taken into consideration. The author's individuality is often exhibited in a strong manner. It is probably the first time that a text-book of this kind has been written by a chemical engineer, not by a professor. The book is free from the rehash from larger works, so often found in elementary text-books.

The last chapter of electrochemistry is interesting in its concise recapitulation of the most important industrial processes using electrochemical methods. The classification employed in this chapter is novel. The author distinguishes primarily between direct-action processes and indirect-action processes, the latter group comprising all processes in which the electrical energy suffers partial or entire transformation into some other form of energy before being applied to the work required, thus including electric furnace processes and electrolysis of fused salts. The weak point of this classification is that processes like the production of caustic soda and chlorine by the mercury-cathode process of Castner on one hand, and by the fused lead-cathode process of Acker on the other hand, are separated from each other, although they belong together logically and industrially. Of course, any attempt at a classification will be found to contain some weak point. This chapter contains, on not more than forty-five pages, a vast amount of detailed information, and if we consider the swift changes in the industry it is easily understood that some of the information given in the book is not fully up to date (*f. i.*, fixation of atmospheric nitrogen, p. 128).

One small and purely formal point calls for comment. Throughout the book the word cation is spelled with th. We know the author is not the only one spelling the word in that fashion; Faraday did so and others are doing so, although it is unquestionably wrong. Cathode is derived from the Greek words cata and hodos, cation from cata and ion, not hion.

A special feature of the book is that as introductory note to each chapter a bibliography is given of important treatises bearing upon the subject matter discussed in the chapter.

The book should be found useful by those who wish to acquire a working knowledge of the first and most general principles which underlie electrochemical science and industry.

HANDBUCH DER ANGEWANDTEN PHYSIKALISCHEN CHEMIE. Edited by Prof. G. Bredig. Leipzig: Johann Ambrosius Barth.

This new pretentious series of German monographs intends to cover the whole field of *applied* physical chemistry. In other words, the purpose is to make the principles of physical chemistry accessible to the chemical engineer—to give a review of the theory, not for the theorist's sake, but for the benefit of the engineer.

This is an excellent programme. It becomes more evident from day to day that in the chemical industries the day of the pure analyst is past, and that chemical and metallurgical engineering must necessarily advance as applied physical chemistry. If the editor of the work and his contributors are able to keep up the standard set in the first volume, reviewed below, the serial will become a monumental and classical work.

Vol. I.: ELEKTROCHEMIE WÄSSERIGER LÖSUNGEN. By Prof. Fritz Foerster. 507 pages. Price (in New York), $6.75 in paper cover, and $7.00 bound.

This is undoubtedly the best book now available on the electrolysis of aqueous solutions. Prof. Foerster is probably best known from the extended research work which, with the coöperation of his assistants and students, has been carried out by him on the electrolysis of chlorides, bromides and iodides. In this work, extending over several years, the author's method showed two general traits: first, an aim to supplement electrochemical research by parallel chemical research (as Prof. Bancroft would say, he endeavored to consider the chemistry of the electrochemistry of any special problem), and, second, an aim to develop the theory for the sake of its practical applications. The numerous papers of the author on this special subject have provided a safe and sane theoretical foundation for a uniform theory of electrolysis of chlorides, bromides and iodides, and this theory has given, and will give, valuable hints to the engineer. Incidentally, we may mention that in studying the behavior of carbon anodes in chloride solutions, Prof. Foerster was one of the first to recognize the value of Acheson graphite and to make Germany familiar with the work of E. G. Acheson.

The whole volume before us, dealing with the broad field of the electrolysis of solutions in water, manifests a broad spirit. There are nine chapters of a more introductory character, filling one-third of the book. They deal with electrical energy and direct current in general, Faraday's law and its practical applications, theoretical consequences of Faraday's law and the electrolytic dissociation theory, migration of ions, voltage at the terminals of a cell, resistance of electrolytes, electric osmosis, generation of electric energy in primary and secondary batteries, general theory of electrolysis.

The other six chapters deal with industrial electrolysis and fill two-thirds of the book. First comes a chapter on the electrolytic production of hydrogen and oxygen gases, then two chapters on special electrochemistry of metals and on application of electrochemistry of metals respectively. The last three chapters (200 pages) which are probably the most important ones, since the information contained in them is not to be found elsewhere in such convenient and complete form, are devoted to electrolytic reduction, special electrochemistry of halogens and electrolytic oxidation.

The book is fully up to date; it is written from a very broad point of view, and at the same time it is accurate in details. Its careful study is highly to be recommended to anybody who has to do with the electrolysis of aqueous solutions.

Vol. II.: Physikalisch-Chemische Mineralogie. By Prof. C. Doelter. 272 pages, with 66 illustrations. Price (in New York), in paper cover, $4.00, bound, $4.35.

This treatise is more tentative than finished, but mineralogists and geologists should find it suggestive in many ways. The author recognizes that methods of physical chemistry applied to mineralogy will be found most useful by indicating the direction in which to proceed in experimental research. This is only natural, since it is largely almost virgin soil that is covered in the book.

Autogenous Welding of Metals by the Oxy-Acetylene Blowpipe and a New Method of Generating Oxygen.

By Andre Beltzer.

For a long time manufacturers, especially in Europe, have been endeavoring to devise means by which the autogenous process of welding could be so cheapened and simplified as to bring this highly effective method into general industrial everyday use.

The following processes have up to the present been used, although to a limited extent: First, welding by electricity; and, second, the Goldschmidt aluminothermic process.

Welding by the electric arc cannot be considered as generally practicable on account of the power required, the special installation necessitated, the danger and inconvenience in handling the electrodes, the difficulty in the regulation of the temperature, and the condition of the atmosphere created by the electric arc by which the texture of the metals is unfavorably affected; iron, for instance, becomes hard and brittle and unfit for working, while copper takes on a porous, spongy condition, etc.

The aluminothermic process is also complicated, involving the building of moulds around the pieces to be welded. The crucibles and moulds used in this process are expensive, and suffer greatly from deterioration.

The application of autogenous welding by the above processes are limited, since they cannot be adapted to complicated assembling and the welding of thin sheets.

The blowpipe is the only simple and practicable solution for the process of autogenous welding, on account of the facility with which it can be handled. The gas which can be most advantageously used in combination with oxygen is acetylene, for the following reasons:

1. The temperature of the oxy-acetylene flame nearly equals that of the electric arc, reaching 3,500° C. (That of the oxy-hydrogen flame is about 2,000° C.). The calorific power of the gas is 13,568 calories per cubic meter (not including the latent heat given out by the condensation of combustion products which is not utilized). The oxidation heat of hydrogen is only 2,800 calories per cubic meter. It can be readily seen that the oxy-acetylene flame is applicable where the heat furnished by the oxy-hydrogen flame would be insufficient, for instance, in the welding of iron of 15 mm. thickness.

2. Whilst the oxy-hydrogen flame is difficult to regulate, the oxy-acetylene flame can be perfectly regulated by the most inexperienced operator, on account of its brightness. It is in fact of the greatest importance in metallurgy that the chemical nature of the flame be perfectly known.

3. Calcium carbide, from which acetylene gas is generated by simple contact with water, is cheap and portable.

Generation of Oxygen.

The greatest factor militating against the development of autogenous welding by the blowpipe has been, up to a short time ago, the high commercial price of oxygen, but owing to the advent of steel receivers, in which the gas is contained under high pressure, the oxygen industry has grown considerably, though still greatly handicapped by the difficulty and cost of transportation. The receivers are necessarily very bulky, being fifteen to twenty times heavier than the contained oxygen, and 150 times the weight of hydrogen. Railway companies charge their highest tariff (same as explosives), added to which is the rent of receivers and the cost of repairs (renewing of valves, painting, etc.).

It has, however, been finally demonstrated that chemically pure oxygen can now be obtained at a reasonable cost below the present price of oxygen in tanks, by the employment of a newly discovered product, called "epurite" (oxygen powder).

Epurite is a substance containing oxygen in a latent form, susceptible of easy liberation on contact with water, analogous to the action produced by water on calcium carbide.

Oxygen so generated is chemically pure, every kilogram of epurite giving about 55 liters of gas at an ordinary temperature of 15° to 20° C. and at 760 mm. barometric pressure. By reason of the low cost and the facility of manufacture, epurite brings oxygen within the reach of all industries, eliminating all danger of explosion arising from the use of tanks or tubes of compressed oxygen, and, being absolutely harmless, enjoys the lowest freight rate accorded chemical products by railway companies.

Welding.

Fig. 1 shows diagrammatically the general arrangement of the apparatus.

One of the oxygen generators A is charged with water and epurite. In the receptacle C is a solution of sulphate of iron, which is allowed to flow into the generator to act as a catalytic agent for the generation of oxygen. The oxygen liberated passes into the gasometer D, and is compressed to 10 atmospheres by the compressor E in the tank F. From the tank the gas passes by a tube through the pressure regulator G and valve H to the blow-pipe K, where the oxygen should arrive at a pressure of 150 cm. water.

The acetylene apparatus NM is arranged so as to give the gas at the above pressure. This pressure of 150 cm. water is calculated so that the exit speed of the gas will counteract the possible back burning of the mixture before reaching the end of the blowpipe.

The blowpipe is provided with metallic gauzes in order to prevent the flame throwing back; the valve of the acetylene tube (fixed to the blowpipe) is at first turned on full, the pressure regulator being adjusted to about a one-half atmosphere; the flow of oxygen is controlled by a valve H, so that there is only one inner cone in the flame which will have only slight fluctuations. The flame now is neutral and ready for use.

A whiter color of the flame and the division of the inner cone in two are indications that there is an excess of acetylene gas, and that the flame is carburating, the molten metal emitting sparks like stars (formation of cast iron). When the flame is oxydizing (shown by the violet tint of the flame) the metal boils and is very bright. For proper welding (steel sheets, for instance,) the joint should be bright. The carburating flame gives a gray porous and non-resistant welding. This flame, together with an oxydizing flame, gives a brittle

welding, and is, moreover, very rarely used. Twenty different sizes of nozzles can be used on the same blowpipe in welding of all thicknesses, from 1 mm. to 30 mm. (0.6 mm. for sheets 1 mm. thick, and 4 mm. for sheets 30 mm. in thickness).

During the process of welding the apex of the cone must be from 2 mm. to 3 mm. distant from the object to be welded. The two edges (previously dressed) are fused, and simultaneously lined and slightly overloaded by the fusing of a rod of the same metal held in the flame.

In this manner iron, steel, copper, brass, cast iron, etc., can be effectively welded.

For thick metals or plates it is necessary to bevel the edges, which can be readily done by many mechanical methods, such as planing, slotting or grinding, and it is well to anneal the sheets or plates, thereby increasing the resistance and quality of the welding.

For brass it is necessary to fill up the interstices of the two sheets to be welded with borax moistened with water, otherwise the volatilized zinc would be deposited on the welded part as oxide of zinc and spoil the welding.

Cast iron which cannot be self-welded must be brazed with copper.

THE BLOWPIPE.

The volumes of oxygen and acetylene used are practically the same. The acetylene is, therefore, not completely burned in the blowpipe according to the reaction:

$$(1)\ldots 2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$$
$$4\text{ Vol.} \quad 10\text{ Vol.}$$

But it is incompletely burned according to the reaction:

$$(2)\ldots C_2H_2 + O_2 = 2CO + H_2$$
$$2\text{ Vol.} \quad 2\text{ Vol.}$$

This is easily understood when we consider that at a temperature of 3,500° C. the water and carbonic acid formed by the reaction (1) are completely dissociated and cannot exist.

To this last fact the success of the oxy-acetylene flame as a welding agent is chiefly due. To bring about the proper conditions for autogenous welding two metals it is necessary to bring them to their melting point without oxidizing or carburating. The hydrogen and carbon oxide generated in the oxy-acetylene flame form a reducing atmosphere and permit the metal to be autogenously welded. These two gases protect the molten metal, and are then burned entirely into carbonic acid and water by the surrounding air. With hydrogen a large excess of gas is necessary, five to six volumes (instead of two theoretically), in order to resist the oxidizing action of the water which is immediately formed in the flame.

In actual use, on account of trials necessary for regulation, a little more oxygen than acetylene gas is used (1.1 volume of oxygen for 1 volume of acetylene). The calibre of the blowpipe necessary for welding sheets from 1 to 3 mm. thick consumes from 100 liters to 250 liters of both gases per hour, and for thick plates of 15 mm. the consumption is 1,150 liters.

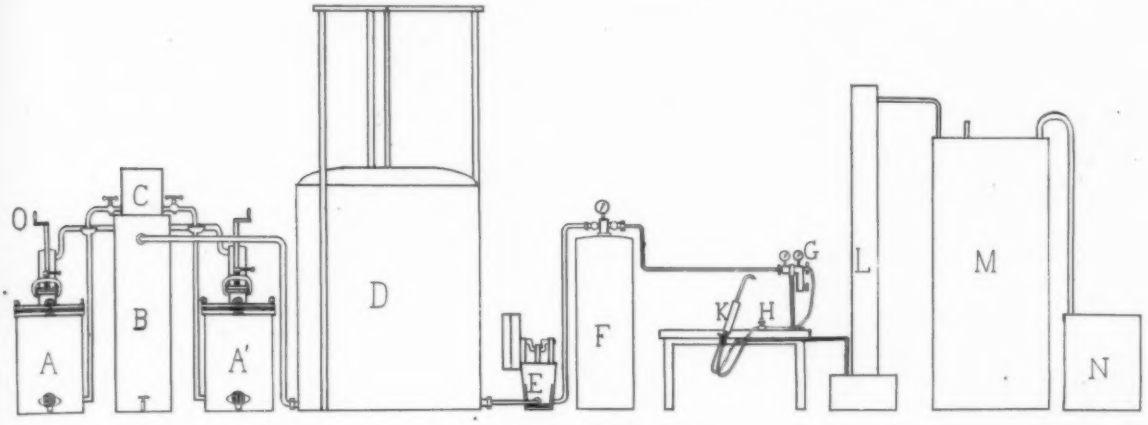


FIG. 1.—ARRANGEMENT OF PLANT.

(A to H, oxygen apparatus; L to N, acetylene apparatus; A and A¹, oxygen generators; B, cleaning tower; C, catalyser vessel; O, agitator; D, gasometer; E, compressor; F, pressure-reservoir; G, pressure-regulator; H, cock; K, blowpipe; L, safety valve; M, gasometer for constant pressure; N, acetylene generator.)

The following table shows the calibres of blowpipe necessary to use for various thicknesses of sheets, etc.:

Calibres.	*Thickness of Sheets.*	*Number of Welded Meters Per Hour.*
0.8 cm.	1 mm.	4.00 meters
1.0 "	2 "	2.00 "
1.2 "	3 "	1.50 "
1.4 "	4 "	1.25 "
1.8 "	5 "	1.00 "
2.0 "	10 "	0.50 "
2.5 "	15 "	0.35 "

Column three shows the amount of work an operator of average ability should accomplish.

It is an established fact that in general the cost of welding by the epurite process is about 50 per cent of the cost of ordinary riveting on work up to and including 7 mm. thick. The cost of welding would be the same as riveting for sheets 8 to 9 mm. in thickness, but more advantageous in regard to strength.

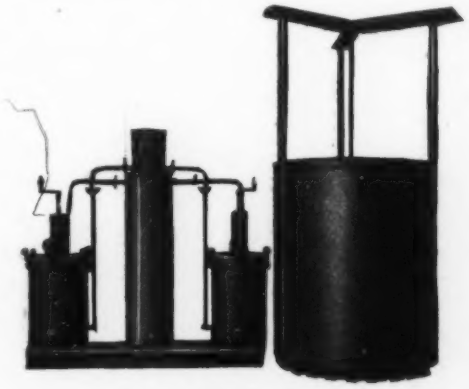


FIG. 2.—EPURITE APPARATUS.

(A, A¹, B, C, D of Fig. 1.)

For heavier sheets the oxygen can be economized by previously heating them with an air-acetylene blowpipe. When the iron is sufficiently heated proceed with the welding.

After trials made by the International Bureau Veritas in Paris, it was ascertained that the tensile strength of the welded part was within 5 per cent of that of the metal itself.

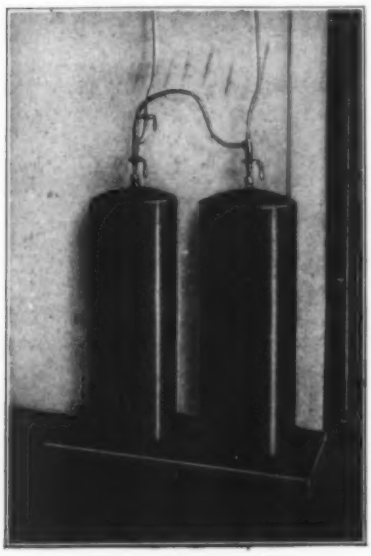


FIG. 3.—OXYGEN RECEIVERS.

It will be seen, therefore, that on account of the facility and the low price at which the two gases, acetylene and oxygen, can be generated, the blowpipe, in its own industrial sphere, is facile princeps.

It can be used by every manufacturer with the best possible results for:

1. Simplification and great improvement in all kinds of assembling (boilers, gasoline and kerosene tanks, piping, etc.)

2. Easy, rapid and sure repairing of all parts (particularly forged), which formerly had to be abandoned on account of flaws, cracks, etc.

3. Work which would be impossible or very difficult to do without the blowpipe.

A New Direct-Reading Electric Thermometer.

In our last issue we mentioned briefly on page 208 a very interesting paper, read by Mr. Edwin F. Northrup at the Milwaukee meeting of the American Institute of Electrical Engineers. The main part of the paper consisted in a detailed discussion of the electric-resistance thermometer. The author explained that resistance thermometers are useful for different particular purposes, and that in any case the particular purpose for which the thermometer is to be used largely determines its special features of construction. Various types of construction to meet different requirements were discussed in detail by the author, who also dealt fully with the different methods of reading resistance thermometers.

FIG. 4.—WELDING WITH BLOWPIPE.

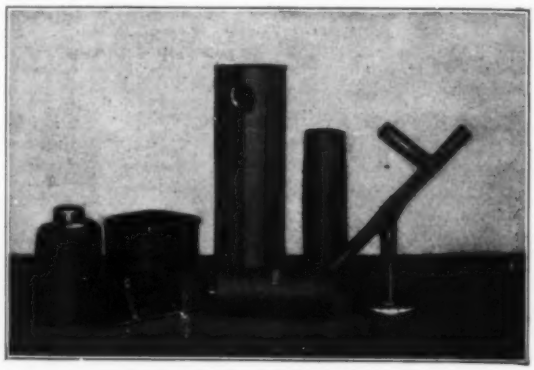


FIG. 5.—WELDED PIECES.

A special instrument described by the author and built by the Leeds & Northrup Co., of Philadelphia, embodies the highest refinements in this kind of measurement. The problem was to get a continuous photographic record of the temperature difference between two mains carrying brine for refrigerating purposes. One main was on the average on a temperature of -38° C., and the other -36.5° C. The average difference was, therefore, 1.5° C. The allowable error in the record was 0.01° C. The methods by which this problem was solved by the author were fully described in the paper.

Another very interesting new instrument also described in this paper is the "ratiometer." If the temperature of the place to be measured is uniform over a small space only, then the resistance winding of the resistance thermometer should be as short and as much concentrated at the end of the tube as possible, and thus permit of placing the entire winding at the point the temperature of which is to be measured. Thermo-couples have in this respect an advantage over the ordinary resistance thermometers, since the end of the thermo-couple has a very small body, which may be placed at the exact point where the temperature is to be measured. This consideration led Mr. Northrup to design a new form of resistance thermometer which is intended to combine the advantages of both.

It is called a ratiometer, since it is a special form of a general type of instrument which measures by direct deflection of a needle the ratio of an unknown to a known quantity, irrespective within wide limits of the operative current used. Thus the ratio measured may be that of an unknown to a known resistance, when the instrument becomes a deflection-ohmmeter, or a capacity-reactance to a resistance, when it can be used as a speedometer, or, as in the present case, a resistance which changes with temperature to a fixed resistance, when it serves as a direct-reading deflection thermometer. Since the angle of deflection of a deflection instrument is apparently doubled by using a mirror giving twice the effective sensibility of a pointer instrument otherwise the same, a system using a mirror has been adopted, and utilized in such a manner that the instrument is quite as portable as a voltmeter or ammeter. The ratiometer will, therefore, enable one to read temperatures as readily as

volts are read from a voltmeter.

Fig. 1 is a sectional illustration of the instrument, while Fig. 2 gives the diagram of connections, and Fig. 3 illustrates details of the deflecting system and the shape of each of the pole pieces.

C_1 and C_2, Fig. 2, are two flat coils mounted on the movable system *a*, *b*, *c*, Fig. 3, having a damping frame of aluminium.

The two coils have like polarity on the same side. The system rotates between two iron crescent-shaped pole pieces of opposite polarity *p* in Fig. 3. The axis of rotation of the system approximately coincides with the center of the outside circle of the crescent. Hence, when the system rotates, one coil moves so as to get more under the pole faces, and the other coil more from under the pole faces. Now, if currents flow through both coils, and in such a direction as to cause both coils to try to move from under the pole faces, the system will seek a position of equilibrium which is independent of the actual value of the currents flowing, and which depends only upon the ratio of the portions of the main current, which divides to flow in the two coils.

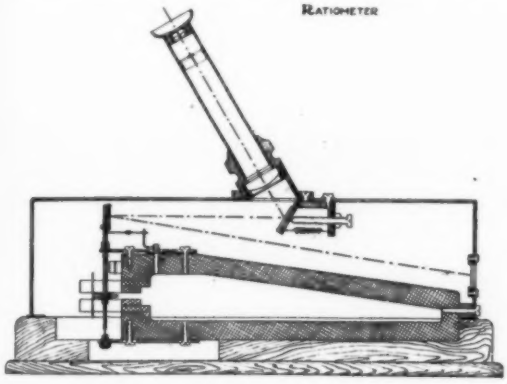


FIG. 1.—SECTIONAL VIEW OF RATIOMETER.

This is true, provided only that the system is under no spring control. The leading-in wires, three in number, are, in fact, made of such delicate strips of silver that they exercise a negligibly small control as compared with the control of the magnetic forces. If, now, the ratio of the currents in the two coils is altered, the system seeks a new position of equilibrium again, independent of the value of the battery current.

Referring to the diagram of connections, Fig. 2, R is a fixed resistance, and T a resistance which varies with the temperature. The extent of the deflection determines the ratio of T to R, whatever be the value of the battery current. Since, also, *y* is a lead wire on the R side equal to *y* on the T side, the method nearly compensates for changing resistance in the thermometer leads. It will be seen that if R = T, the battery Ba sends the same current through both halves of the system. Now, R is a resistance of wire of zero temperature coefficient, T a resistance of wire of a high temperature coefficient. Therefore, if T is placed, for instance, in a furnace, T changes according to the temperature of the furnace, R remains constant. The ratio of T to R determines the deflection, which therefore gives directly the temperature of T.

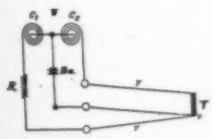


FIG. 2.—DIAGRAM OF CONNECTIONS.

The reading device is mostly explained by Fig. 1. The scale is of translucent celluloid, mounted on the lower part of the front of the case, and is divided in degrees centigrade. In the telescope the scale is seen brilliantly illuminated by ordinary room light.

The telescope can be removed when the instrument is to be packed in its carrying case. The special shape of the aluminium frame of the system is adopted so as to give good damping, and this makes the instrument nearly dead-beat. The instrument operates for temperature measurements on three or four dry cells connected in series, or it may be used with a commercial current from a hand magneto.

To read any temperature it is only necessary to place the thermometer, joined by a lamp-cord to the instrument, in the place where the temperature is required, and look into the telescope. The scale appears to move under the cross-hair of the eye-piece to the temperature reading.

The ratiometer may be made sensitive to temperature changes of about 0.1° C. or less, and can be relied upon to be as accurate as the scale of originally calibrated, with the exception of possible fluctuations of 1, or at most 2°. These irregularities are due to imperfections in the construction, or imperfect balancing balancing of the coil. The error is not progressive, however, and fair reliance can be placed upon the indications. The instrument is especially valuable for rapidly taking the high temperatures of furnaces and the like.

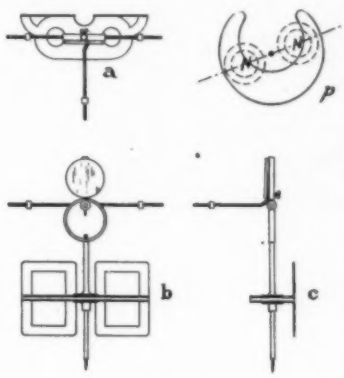


FIG. 3.—DETAILS OF DEFLECTING SYSTEM.

The ratiometer is made by the Leeds & Northrup Co., of Philadelphia.

Thermit Repair of a Gold Dredge.

The repair of a gold dredge, recently made in California, is an interesting illustration of the ease with which thermit may be applied to the greatest advantage to repairs of machinery in remote mining fields. As is well known, thermit is a mixture of finely divided iron oxide and aluminium, and the reaction (which is started by igniting a special ignition powder with a match) consists simply in the combination of the aluminium with the oxygen of the iron oxide. Since this gives out an enormous amount of heat, the iron set free is obtained in form of a superheated liquid soft steel at 5,400° F. within 30 seconds after starting the reaction.

It is self-evident that it is possible to do many things with such superheated liquid steel for the repair of iron or steel machinery and for other purposes in iron and steel metallurgy. Other practical advantages of the method are the simplicity of the necessary outfit and the ease of transporting it. Since the process has repeatedly been discussed in detail in our columns, nothing further may be said here on the process in general.

The repair to be described in this note was made at Wallace, Calaveras County, California, where the Mokelumne Mining Co. (Mr. William C. Colley, general manager) had some troubles with the gold dredge shown in Fig. 1.

The trouble was principally with the upper "tumbler;" *i. e.*, the driving wheel to which the whole bucket line is hung and which drives it by teeth or sprockets. This bucket line consisted of sixty-four buckets, each weighing 1,100 pounds, and having 5 cubic feet capacity.

The tumbler shaft was 12 inches to 13 inches in diameter, and had a hub keyed to it by two heavy quartering keys. The hub was tapering and 20 inches on the large end. The shell with the heavy sprockets slipped over this hub and was drawn over the taper by three bolts, 1¾ inches in diameter.

Through some fault, probably of alignment, the whole

tumbler, hub and shell crept along the shaft, notwithstanding heavy bands designed to prevent this, and through a faulty and slightly large bore of the hub the keys could not be kept in

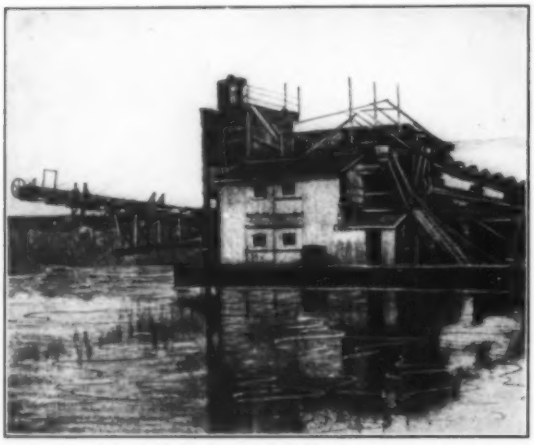


FIG. 1.—COLD DREDGE.

place and were gradually "chewed up" by the working of the hub.

The Pacific representative of the Goldschmidt Thermit Co.,

FIG. 2.—BEFORE THE THERMIT REPAIR.

Mr. L. Heynemann, 2721 Clay Street, San Francisco, Cal., was called in for consultation, and after examining the shaft and tumbler he concluded that it was possible to "freeze" or fuse the tumbler immovable to the shaft, that is to say, to cast a thermit steel band on each side of the hub which would fuse both to the shaft and the face of the hub.

The repair was made in the beginning of April, the tumbler shaft and hub being placed in the field near the dredger with a frame built over it. Fig. 2 shows the nutways in the hub and also that the smaller part of the shaft (12 inches in diameter) was on the large taper end of the hub, while the larger part (13 inches in diameter) was on the smaller end of the taper. This difference resulted in differences in the thermit bands on each end, the band on the 12-inch end taking more metal than on the 13-inch end.

FIG. 3.—HEAVY BAND COMPLETED.

The heavier end was treated first. On April 10, after rain in the forenoon, both cores were fitted. On April 11, late in the afternoon, after the shaft had been heated to a "black red," the reaction took place. The crucible containing the thermit mixture was placed above the mould, the principle being essentially the same as is now so well known from the practice of welding rails.

Fig. 3 shows the heavy band completed, with cores, gate and riser removed. It shows the nutways and also the fin on the horizontal plane through the parting shaft center, where the top and bottom cores met.

On April 12 the cores were fitted for the other end, and by 10 o'clock that night they were ready for the reaction. The

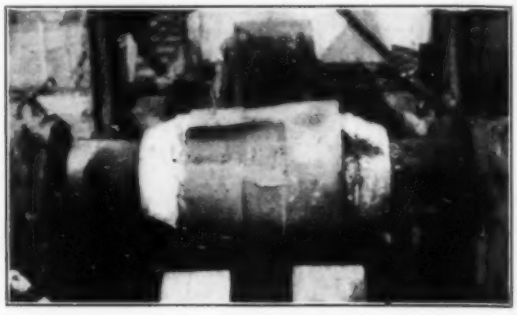


FIG. 4.—SHAFT IN PLACE.

news that this work was to be done had spread all over the country, and the natives came in all kinds of rigs to witness this peculiar kind of fireworks. The result was eminently satisfactory from an engineering point of view. Fig. 4 shows the shaft in place on the top of the dredge and the thermit bands on each side of the hub before the shell and bucket had been replaced.

American Foundrymen's Association.

The enormous success of the Cleveland meeting, held from June 5 to 7, is indicated by the fact that the registration passed the 800 mark. The secretary of the Association, Dr. Richard Moldenke, was as ever the soul of the proceedings. A special feature of this year's convention was a fine and extensive exhibition of foundry supplies and equipment, which was so much appreciated that it is intended to make such exhibits a permanent feature.

The president, Mr. Thomas D. West, presented an address on the need of a practical education. He urged that "the education of our youth should be confined to that which can be directly utilized." He also demanded specialization.

The committee on standard methods for the analysis of iron (H. E. Diller) presented a report on the determination of total carbon and sulphur. This will be given in full in our next issue. Among the papers presented were the following: A. E. Outerbridge, on the beneficial effects of adding high-grade ferro-silicon to cast iron; R. Moldenke, on foundry tests of coke made by the United States fuel testing plant at St. Louis; R. West, on comparative designs and working of air furnaces; F. L. Antisell, on electricity in the foundry; C. Vickers, on alloys; C. H. Benjamin, on erperiments on the strength of various cast iron machine parts; W. K. Barrows, on influences of different ore mixtures on the resultant pig iron from the standpoint of the foundryman; W. M. Carr, on the thermit process in foundry practice. Abstracts of various of these papers will be given in our next issue.

Visits were paid to the Case School of Applied Science and to the works of the Brown Hoisting Co., Wellman-Seaver-Morgan Co., Electric Controller & Supply Co., and the Lorain Steel Co.

Mr. W. H. McFadden, of Pittsburg, is the new president.

Notes.

The Zucker & Levett & Loeb Co., manufacturers of complete electroplating outfits and supplies, as well as low-voltage dynamos for general electrolytic work, have opened temporary offices at 250 Tenth Avenue, New York City. During May their factory and offices on West Twenty-fifth Street were destroyed by fire. They now occupy a large new factory adjoining their old premises, consisting of Nos. 516 to 524 West Twenty-fifth Street, where they will have much larger facilities than before for manufacturing electroplaters' supplies. They announce that in spite of the serious nature of the fire they are now able to make delivery of goods from their new factory.

Mr. Chas. J. Bogue, the well-known New York manufacturer of low-voltage dynamos for electroplaters, electrotypers and for general electrolytic and electrometallurgical work, announces that on June 16, 1906, his business was incorporated under the name of Chas. J. Bogue Electric Co., 213 to 215 Center Street, New York City. Mr. C. J. Bogue is president, Mr. L. Robertson treasurer, and Mr. F. Plante secretary of the company.

Messrs. J. H. Gautier & Co., Jersey City, N. J., manufacturers of black lead crucibles, whose works were badly damaged by fire during March last, announce that their works are again in operation, and they are able to make deliveries, their facilities being better than ever before.

Thermit.—An illustrated pamphlet, entitled "Thermit, What You Can Do With It," has recently been issued by the Goldschmidt Thermit Co., of New York City. It describes in a simple and easily understood language the numerous applications to which thermit can be put in the industries, and especially in metallurgy.

Gas Power.—An illustrated pamphlet recently issued by the New York Electrical Society, contains an address by R. T. Lozier on fundamental principles of gas engines and gas producers. The De La Vergne Machine Co., New York City, who are the sole licensees for the manufacture of the Koerting gas engine and producer in the United States, have just issued a ten-page folder describing the Koerting four-cycle gas engine and suction producer. These engines have met with remarkable success in Europe, where a large number have been installed in municipal lighting plants, factories and other places.

Water Power.—Mr. H. P. Broughton, general manager of the Great Northern Power Co., of Duluth, Minn., states that the first 10,000-hp. unit will be put in operation at their power plant about September. These units are of the vertical shaft type manufactured by the General Electric Co., and operated under a head of 375 feet. The Great Northern Power Co. has 200,000 hp. available, 30,000 of which will be put in operation within the next year. The plant is situated 3 miles from the city limits of Duluth, the distance for transmission to their distributing center being 14 miles. The first electrochemical plant to use this power will probably be a calcium carbide plant operating under the patents of Mr. H. L. Hartenstein, which has been manufacturing this product at Constantine, Mich. Several of Mr. Hartenstein's furnace patents were abstracted in our June issue on page 257.

Ice and Refrigerating Machinery.—A 48-page pamphlet, describing various types of horizontal and vertical ammonia compression refrigerating machines and equipment for ice plants, breweries, packing houses, etc., has just been issued by the De La Vergne Machine Co., foot of East 138th Street, New York. The book is illustrated by many fine half-tones, a feature of these being the clever and artistic arrangement of composite views of plants installed in various parts of the world. The booklet should be of special interest to iron metallurgists on account of the success of Mr. Gayley's dry-blast system and the use of refrigerating machinery for drying the blast.

The Wilson-Maeulen Co., engineers, manufacturers, importers and dealers in pyrometers and photo-microscopical metallurgical apparatus, have opened offices at 110 Liberty Street, New York City. For use in connection with thermo-couples of the Le Chatelier type they will have two types of recording instruments, and will also be able to supply radiation and optical pyrometers.

The Green Mountain Mining Co.'s mill at Silverton, Col., which was described at length in our Vol. III., pp. 122 and 163, was seriously damaged by a snowslide on March 17, but has been rebuilt and is again in running order. This plant was designed and built complete from the grass roots up by the Traylor Engineering Co., and was only just completed at the time of the landslide. As soon as the news of the damage was received in New York orders were given to the Traylor Engineering Co. to rebuild whatever was damaged, and work was begun at once. The reconstructed building is designed for two units of 140 tons capacity each per day, but only one will be operated at present. There is sufficient power to bring the output up to 280 tons whenever desired. Double 8-hour shifts will be run for the present, each shift requiring about forty in the mine and twenty in the mill. A novelty in the Green Mountain Camp which will be watched with interest is the Traylor centripact screen. Eleven have been introduced in the Green Mountain mill. Mr. W. M. Turner, formerly of the Cobra Mining Co., of Santiago Province, Cuba, is the new foreman of the resurrected Green Mountain mill, taking the place of D. R. Hickey, who lost his life in the snowslide which demolished the mill March 17.

Electric Power from Blast Furnace Gases.—The very important saving which is attainable by utilizing to the utmost the calorific value of the "waste gases" of blast furnaces, has been the subject of various articles and notes in this journal; reference may be made especially to two articles by F. duP. Thomson and A. J. Rossi, on pages 95 and 150 and 190 of our Vol. III., respectively. It is well known that the Lackawanna Steel Co. and the De La Vergne Machine Co. were the pioneers in this field in this country. Important advances are now being made in the same direction by the United States Steel Corporation. The entire gas-engine driven electric generating equipment of their steel mills, except for two units placed as experimental orders with other builders, has been designed by the engineers of the Allis-Chalmers Co., and is now under construction in its shops. Orders for gas-electric generating units recently placed with Allis-Chalmers Co. comprise 15,000 hp., to be furnished for the Illinois Steel Co., 4,000 hp. for the Homestead plant of the Carnegie Steel Co., and 35,000 hp. for the Indiana Steel Co. Each unit is of 2,000-kw. capacity. It consists of a horizontal twin-tandem Allis-Chalmers gas engine, direct connected to an Allis-Chalmers generator. All of the generators except two are designed for alternating current, 25 cycle, three phase. In addition to these electrical units the Allis-Chalmers Co. is building equally large gas blowing engines for the United States Steel Corporation, four of which are to be installed in the Homestead plant. Of the remaining engines purchased for this purpose, which are to be constructed by other companies, all will be built under a license from Allis-Chalmers Co., owner of the Slick patents covering the blowing "tubs" adopted for these machines. Each blowing engine has a capacity of 3,500 hp., and will deliver 30,000 cubic feet of free air per minute against a pressure of 18 pounds per square inch, which is ordinarily the maximum, but it is so designed and proportioned that it can be operated at any pressure up to 30 pounds. Gas engines thus far purchased from Allis-Chalmers Co. by the United States Steel Corporation will have an aggregate normal capacity of 68,000 hp., and represent a value of over $2,000,000.

E. J. Lavino & Co., Bullitt Building, Philadelphia, Pa., have been appointed the American representatives of Keller, Leleux & Co., of Livet, France, for the introduction of the Keller furnace and processes for the manufacture of high-

grade steels and ferro-alloys. Messrs. E. J. Lavino & Co. are well known throughout the iron and steel industries in this country as large importers and dealers in ores, metals and alloys.

The Weston Electrical Instrument Co., Waverly Park, Newark, N. J., have this year taken their Mr. Caxton Brown into the Newark factory as secretary of the company and sales manager, and in his place have put Mr. Stanley Brown as manager of the New York office. In connection with this office there has been installed a repair department, whose duty it is to take care of the repairs in the Metropolitan district, and particularly to look after emergency calls. This new feature has been very warmly welcomed by the many users of Weston instruments in New York City, and has enabled the manufacturer to insure a higher degree of satisfaction to his customers than ever before.

Obituary.—From Germany comes the report of the death of the distinguished professor of iron and steel metallurgy in Freiberg, Geheimer Bergrat A. Ledebur, at the age of 69 years.

Personal.

Mr. J. B. Tyrrell, mining engineer, who has spent the past eight years in the Klondike, Yukon Territory, has opened offices at 266 McLaren Street, Ottawa, Can., and is prepared to report on mining properties of any kind.

Dr. Schuyler Skaats Wheeler, president of the Crocker-Wheeler Co., Ampere, N. J., sailed June 14, on the Lloyd steamship "Barbarossa," for a short European trip. He was accompanied by Prof. Francis B. Crocker, professor of electrical engineering at Columbia University, who has been associated with him in business for many years.

Dr. Rossiter W. Raymond, the distinguished secretary of the American Institute of Mining Engineers, received the honorary degree of LL. D. from Lehigh University on Commencement Day, June 13. This is the first time that this degree has been bestowed by Lehigh on any one. Wearing for the first time the garb of an alumnus of Lehigh, Dr. Raymond addressed the graduating class on "professional ethics."

Dr. Joseph W. Richards, of Lehigh University, with Mrs. Richards and their three children, sailed from New York on June 29 for Mexico, where they will pass the summer vacation. Dr. Richards will attend the International Geological Congress, which meets in the City of Mexico in September, and make an extended "metallurgical journey" through Central Mexico before returning in October.

Digest of U. S. Patents.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Discharges Through Gases. Ozone.

(*Continued from page 252.*)

No. 507,975, Oct. 31, 1893, Jackson De Neal, Toledo, Ohio.

Generates combustible gas from a solid material such as charcoal, coal siftings, iron ore or garbage and oil. The solid material is fed downward and the oil upward into the space between the adjacent ends of two horizontal electrodes, between which an electric current is passed. The reaction chamber is surrounded by a shell, which has air passages and dampers to control the temperature. The electrodes are insulated by tubes of glass or mica, etc.

No. 511,330, Dec. 26, 1893, Ernst Fahrig, Marseilles, Ill.

Produces oxygen by passing air through a revolving fan, thence through a filter of velvet coated with an albuminoid solution, to remove suspended matter and a portion of the nitrogen, and thence into a heated retort containing sodium manganate and lime. These absorb the oxygen, which is then driven off by the introduction of dry steam under pressure. The steam carries off the oxygen and is condensed therefrom. The oxygen is heated, dried by calcium chloride and sulfuric acid, cooled in iced coils and ozonized in boxes having alternate flat electrodes of glass coated with tin foil.

No. 512,265, Jan. 9, 1894, Emile Andreoli, London, England.

Shows several ozonizers employing electrodes having points near to but out of contact with the dielectric. One apparatus comprises a closed box of marble or wood lined with pitch or glass, containing alternate spaced electrodes having opposed points separated by a plate of glass or mica. The air or oxygen may be cooled by a coil surrounded by ice and salt; by an initial compartment in the ozonizer containing ice and salt; or by cooling the entire ozonizer. The electrodes consist of tinned iron, copper, aluminium or tin or a tin alloy. One electrode may be flat or have pins carrying balls opposing the points of the other electrodes, the pins being tinned. Copper-wire brushes may be substituted for the points. In another construction a rectangular box of glass or porcelain is fitted with a plate having points on both sides, arranged between two sheets of tin or tin-plate, but separated therefrom by glass or mica. Enameled flat electrodes may be used; also electrodes having points cast thereon or punched therefrom, or provided with saw-shaped strips or consisting of fine wire stretched upon glass. Another type employs a tinned metallic core, or one of enameled iron or copper, in a tube of glass or earthenware closed at both ends by insulation. Around the tube is a cylinder having inwardly and outwardly projecting points, the latter surrounded by a metal tube electrode enameled inside and outside, or by a tube of glass and a tubular electrode. In another apparatus pairs of plates alternately pointed and plain and sheets of glass are arranged in the position of the laths of a Venetian blind. In another form, one electrode is a comb consisting of a tinned metal rod, to which are fixed metallic bands having teeth. The other electrode consists of metal rods inclosed in glass tubes and facing opposite teeth, or of enameled metal rods. The glass tubes are wound at intervals with fine copper wire, forming bands which are soldered to some of the teeth of the combs. The air to be ozonized is filtered through cotton or wool.

No. 523,262, July 17, 1894, Gustave A. Cannot, London, England.

An apparatus for converting a mixture of oxygen and chlorine into dichlor monoxide, comprising a glass tube within which is arranged a central electrode of copper wire coated with silver, gold or platinum, and wound externally with a similar spiral wire electrode. The whole is inserted into and spaced from a glass gas-conveying tube by glass beads. The gas tube is surrounded by a glazed porcelain tube, contained in an outer case of thin metal through which cold water is circulated. The chlorine is preferably produced by the action of hydrochloric acid upon manganese peroxide; the oxygen by the action of sulfuric acid upon manganese peroxide, both in steam-jacketed vessels. The chlorine is purified by passing it through a sodium chloride solution, and both the chlorine and oxygen by washing them. The gases are then dried and mixed. The drier is a rectangular box lined with glass, having a perforated horizontal partition carrying pumicestone wet with sulfuric acid. The chlorine and oxygen are admitted at one end of the box, the chlorine above the partition and the oxygen below it, their specific gravities causing them to mix. The chlorine monoxide is absorbed by a solution of caustic soda or potash.

No. 523,263, July 17, 1894, Gustave A. Cannot, London, England.

Employs the apparatus of the preceding patent for the production of hypochlorous acid, employed for bleaching, especially of peat fiber. The gaseous product, chlorine monoxide, is passed through water, with which it unites to form the acid.